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A Comparative Assessment of Paper-based and Computer-based Maintenance Information Delivery Systems

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With the numerous problems associated with paper-based technical manuals (TMs) and the eventual, inevitable change to some type of electronic presentation, it is important to compare the efficiency and effectiveness of electronically delivered technical information to that of paper-based TMs.

In the first of a two-part evaluation, 28 Navy NATO SEASPARROW Surface Missile System (NSSMS) technicians used both the paper-based TMs and an automated presentation system to support troubleshooting two NSSMS problems. In the second part, 34 individuals from the NSSMS community (primarily technicians and instructors) discussed how such a system would be implemented in the fleet, and the impact of innovative changes on the Navy's personnel subsystem.

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Results from the first part demonstrated an improvement in troubleshooting performance when the automated presentation system was used to display troubleshooting information. Specifically it was found that: (1) The more difficult the problem, the more effective the automated presentation system. (2) Use of the automated presentation system led to significant reductions in troubleshooting time (up to 40%) and error rates (fewer false replacements and fewer unnecessary tests), while resulting in a 100 percent success rate for fault isolation. (3) Regardless of experience level, technicians were more successful and took less time locating additional information when using the automated presentation system. (4) Technicians preferred an automated presentation system over paper-based TMs.

Based on the results from the second part of the evaluation, the authors conclude that the transition from a paper to electronic medium for presentation of technical information will have a major impact on the Navy's personnel subsystem in two important respects: (1) the way in which technicians interact with technical information contained in the automated data base, and (2) the changing role of maintenance technicians as they become fully or even partially supported by an automated presentation system. The authors also conclude that for shipboard maintenance applications, the automated presentation system must be available at dispersed locations to ensure adequate access and availability.

FOREWORD

This effort was conducted in support of the Joint Service Manpower and Training Development Program sponsored by the Office of the Under Secretary of Defense, Engineering and Logistics Support, Work Unit Code 99000N: Personal Electronic Aid for Maintenance (PEAM). The monitoring organization was the U.S. Army Research Institute, PERI-IP. The work described in this report involved the collection of both objective and subjective data for comparing and evaluating a computer-based maintenance information delivery system as an alternative to conventional paper-based maintenance manuals.

Appreciation is expressed to the Commanding Officer, Combat Schools Technical Command, Mare Island, California, and the Commander, Naval Surface Forces Pacific, San Diego, California, for providing participants. Appreciation is also expressed to Code 4Y40 of the Naval Ship Weapon Systems Engineering Station, which provided subject matter experts during the development of the data base.

This report is the fourth Navy Personnel Research and Development Center report addressing electronic presentation of technical information: (1) NPRDC Technical Note 87-30 compares design features of four developmental electronic technical information delivery systems; (2) NPRDC Technical Note 87-41 analyzes troubleshooting performance of maintenance technicians who used both paper-based maintenance manuals and a computerized information presentation system; and (3) NPRDC Technical Report 88-6 compares alternative computer-based print, audio, and graphics methods for presenting job task instructions. The research in this report is part of a larger PEAM evaluation reported by the Army Research Institute in Schurman and Kincaid (1988) and Wisher and Kincaid (1988).

This report is intended for use by military and civilian personnel concerned with designing or developing automated technical information presentation systems. Comments and recommendations regarding this report are welcome.

This Center's human factors program and staff, including the authors of this report, were organizationally transferred to the Naval Ocean Systems Center, San Diego, in March 1988. For further information on this or related work, contact Dr. Smillie at the Naval Ocean Systems Center, ATTN: Code 445, Combat Systems Branch, San Diego, California 92152-5000, or call (619) 553-8015 or AUTOVON 553-8015.

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SUMMARY

Problem

The printed technical manual (TM) is the primary means for conveying the information needed to support the operation and maintenance of virtually all systems and equipments in the Navy. Paper-based TMs are heavy and voluminous, and their development and updating are both costly and time-consuming. The paper medium has inherent constraints inconsistent with efficient organization of technical information. In particular, information is static and only presented at a single level of detail.

Purpose

The primary purpose of this effort was to compare the efficiency and effectiveness of electronically delivered technical information with that of paper-based TMs in supporting the information needs of Navy technicians. A secondary purpose was to obtain information related to the implementation of an automated presentation system from prospective users in the surface fleet.

Part I: Comparative Assessment

The technical objective of Part I was to evaluate an automated presentation system as a maintenance aid for the NATO SEASPARROW Surface Missile System (NSSMS).

Method

Two troubleshooting problems (firing officer console and director control) were defined by subject matter experts as representative of the types of problems encountered by NSSMS fleet technicians. A scenario was developed for each problem. The two delivery methods used to present troubleshooting information were a Sun model 3/75 computer, that contained the data base, and the standard technical manuals for the NSSMS MK57 Mods 2 and 3.

Twenty-eight NSSMS "C" school instructors and students participated in the study. Each participant was randomly assigned to a two-problem set. Combinations of presentation and delivery method were balanced to avoid experimental bias.

The independent variables of technician experience level, technical information presentation method, and NSSMS troubleshooting problems were arranged in a 2 X 2 X 2, mixed design. Data were collected on 14 different time and error measures.

Results

A statistically significant interaction was obtained between the presentation method and troubleshooting problem. Put simply, this means that the effect that the paper- and computer-based delivery systems had on the performance measures was not the same across the two troubleshooting problems administered. When analyses were performed on the performance measures for the firing officer console problem, results showed significant differences between the two technical information delivery methods. Use of the automated presentation system for the apparently more difficult firing officer console problem resulted in a 60 percent reduction in total troubleshooting time. More importantly, there was a 100 percent success rate in fault isolation using the automated presentation system, compared with a 53 percent rate using the paper-based TMs. None of the technicians using the automated presentation system made false replacement errors, while those using TMs averaged slightly less than one false replacement (0.70) per problem. Other error measure comparisons also supported the effectiveness of the automated presentation system. Technicians who used the automated presentation system checked twice as many proof points and were 12 times less likely to commit an "out-of-bounds" error. (An out-of-bounds error is an incorrect deduction that the testing of one or more printed circuit cards will provide useful information for isolating the failure when, in fact, the card selected for testing is functioning properly and is not contained within the boundaries of the fault path.) Further, when the technicians used the automated presentation system, they performed fewer tests (a ratio of 1:1.3) and had fewer invalid checks (a ratio of 1:3) compared to when they used the TMs.

There was only one difference between the performance of inexperienced and experienced technicians, which occurred when the participants were asked to locate narrative information for the two faulty printed circuit cards. When using the TMs, the experienced group had a higher success rate (71%) than the inexperienced group (33%).

In a user questionnaire, the participants rated the automated presentation system as an improvement over TMs for the NSSMS in terms of efficiency and effectiveness in providing needed maintenance information.

Part II: Implementation Issues

The technical objective of Part II was to obtain information related to fleet implementation of an automated presentation system.

Method

Information was collected from 34 people--25 NSSMS technicians, 7 NSSMS "C" school instructors, an NSSMS documentation expert, and the project director for the development of an automated data base for the MK 15 (PHALANX) Close-In Weapon System. Questionnaires and open-ended interviews were used to collect the data on (1) implementation concerns of the various anticipated users, and (2) impact of innovative changes on the Navy's personnel subsystem.

Results

A consensus was reached on several issues related to the implementation of an automated technical information delivery system. For example, it was felt that multiple delivery devices and copies of the data base should be located throughout the weapon system they support to ensure adequate coverage, availability, and survivability. Backup copies of the media used to store the automated technical information data base were also considered to be a necessity for shipboard applications.

Revisions and updates should be fast and easy to perform, resulting in completely revised "manual sets" of the automated system's data base using magnetic or optical media.

While a need for training in the operation of the automated presentation system itself was noted, the automated presentation system could, in turn, be used to support both on-the-job and participatory shipboard training.

Since many advanced weapon systems in the Navy contain built-in test (BIT) capabilities, the power and advantages of an automated presentation system would not be fully realized if it were restricted to a single interface; that is, between the user and the technical information data base. Accordingly, it was felt that an interface should be developed that would allow the automated presentation system to initiate BIT routines and process BIT data directly. With this "expert reasoning" capability, the automated system could then evaluate BIT results and provide the technician with a menu of alternative, most likely, next actions to perform; thereby minimizing the role of the technician as a data transfer agent and maximizing that person as an analytic decision maker. Interfaces with other shipboard data bases have to be considered, such as the shipboard non-tactical ADP program (SNAP), the consolidated automatic support system (CASS), etc., to provide maximum usage of available maintenance data and to simplify parts ordering and documentation of maintenance actions.

Conclusions

To summarize, troubleshooting performance was improved when the automated presentation system was used to display troubleshooting information for the NATO SEASPARROW Surface Missile System. Specifically:

1. The more difficult the problem, the more effective the automated presentation system.

2. Use of the automated presentation system led to significant reductions in troubleshooting time (up to 40%) and error rates (fewer false replacements and fewer unnecessary tests), while at the same time resulting in a 100 percent success rate for fault isolation.

3. Regardless of experience level, technicians were more successful and took less time locating additional information when using the automated presentation system.

4. Technicians preferred an automated presentation system over existing paper-based TMs.

The authors conclude that the transition from a paper to electronic medium for presentation of technical information will have a major impact on the Navy's personnel subsystem in two important regards: (1) the way in which technicians interact with technical information contained in the automated data base, and (2) the changing role of maintenance technicians as they become fully or even partially supported by an automated presentation system. The authors also conclude that for shipboard maintenance applications, the automated presentation system must be available at dispersed locations to ensure adequate access and survivability.

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INTRODUCTION

Problem

The printed technical manual (TM) is the primary means for conveying the information needed to support the operation and maintenance of virtually all systems and equipments in the Navy. Paper-based TMs, however, are heavy and voluminous. Constraints inherent within the paper medium are inconsistent with efficient organization of the information. In addition, the technical information is static and only presented at a single level of detail. Finally, TM development and updating are both costly and time-consuming.

Volume and weight of paper TMs have reached unwieldy proportions. Duffy (1985) noted that a military aircraft introduced in 1950 required 1,800 pages to document the entire operation and maintenance system. By 1975, that figure had increased 14,000 percent to 260,000 pages for the Navy's F-14 fighter. The technical documentation to support the F/A-18 fighter is in excess of 700,000 pages. In a recent field survey, representatives from the Space and Naval Warfare Systems Command determined the weight and volume of paper-based information stored aboard different types of Navy platforms (Space and Naval Warfare Systems Command, 1987). Results showed that the weight and volume of paper and associated storage containers aboard the USS VINCENNES (CG-49) totaled 71,503 pounds and 1,806 cubic feet. This weight is equivalent to 142 pounds for each man assigned to the Aegis-class cruiser.

Searching through multiple volumes of TMs to obtain needed information can become a frustrating task. A dramatic example of this access problem was described in a report issued by the General Accounting Office (1979). The report noted that to isolate and repair one particular radar malfunction on a C-141 aircraft, technicians had to refer to, and cross-reference, 165 pages in 8 separate documents. An unfortunate by-product of this access problem is that it tends to discourage users from following maintenance procedures specified in the TM. Rue and Lorenz (1983) reported that the bypassing of critical procedural steps in the TM was a major factor in the unnecessary removal of line replaceable units on Air Force avionics equipment. Specifically, their study found that 13 percent of the 1,008 unnecessary replacements of non-faulty components was attributed to ineffective TMs (e.g., troubleshooting procedures were too difficult to follow, or took too long to perform, or were inaccurate).

Another major shortcoming of paper-based TMs is that the information is static. Hence, the TM is not readily adaptable to the needs of the user. For example, an inexperienced technician (or one who has not worked on a particular price of equipment for some time) may require more detailed information than is provided in the TM to perform such functions as locating test points and removing, replacing, or adjusting components. Conversely, a highly experienced technician may have performed a particular maintenance task so often that little more is needed than a checklist to ensure that no maintenance step is overlooked. In addition, the inherent structure of paper-based TMs prevents a dynamic interactive exchange between the information source and user. For example, TMs lack the capability to (1) provide hands-free access to, or alternative methods for delivery of, needed technical information (e.g., voice input or text-to-speech output); (2) highlight or animate selected portions of the technical information on demand (e.g., emphasizing the physical location of components using flashing arrows or highlighting the path(s) of a signal across multiple pages of schematic diagrams); or (3) provide direct, on-line access to computerized data banks (e.g., spare parts supply information or historical records of equipment casualties and their solutions).

Finally, paper-based TMs have large time and dollar costs associated with production, distribution, updating, and correction. In 1978, the Air Force estimated that it spent $70 million per year to add new manuals or revise existing ones (General Accounting Office, 1979). More recently, it has been estimated that the per page development cost for TMs within the Department of Defense ranged from $250 for a standard manual to more than four times that for user-oriented ones (Duffy, 1985). Beyond cost considerations are the inherent delays in updating TMs to reflect modifications in hardware installation and engineering changes, or to correct errors and discrepancies identified by the TM users. In regard to the latter, Chenzoff and Joyce (1983) reported that errors in TMs that affect the safety of the user are processed quickly, in as short a period as 2 weeks. Lower priority changes, on the other hand, require TM originators to submit advance change notices within 90 days and subsequent delivery of actual changes within six months.

In an attempt to remedy the foregoing deficiencies within the paper medium, the Office of the Secretary of Defense (OSD) recommended that the services initiate research and development efforts aimed at improving the overall quality, management, and delivery of military technical information. One outgrowth of this OSD recommendation was the development of a portable computer-based technical information delivery system called the Personal Electronic Aid for Maintenance (PEAM).

Background

The PEAM project began as an exploratory development effort jointly sponsored by the Naval Training Systems Center (NTSC) and the Army Project Manager for Training Devices. The initial effort, conducted from FY80 to FY82, resulted in the formulation of a conceptual definition for PEAM together with detailed specifications for developing its computer hardware and software systems. Also, during FY82, a memorandum of understanding was signed by the Commander, Army Research Institute and the Commanding Officer, NTSC. The memorandum established agreements, support, and resource responsibilities for the full-scale engineering development of PEAM. The latter effort culminated with the delivery of four PEAM prototype devices from the contractor in FY86. (See Schurman and Kincaid (1988) for a detailed description of the physical and operational features of the PEAM prototype.)

Concurrent with the PEAM engineering development, OSD tasked the services with the responsibility to test and evaluate the PEAM concept as an alternative to paper TMs. In FY85, OSD tasked both the Army Research Institute and the Navy Personnel Research and Development Center to design and conduct field tests of PEAM in their respective services. This report describes the Navy test and evaluation. (See Schurman and Kincaid (1988) for the Army test and evaluation.)

Purpose

The primary purpose of this effort was to compare the efficiency and effectiveness of electronically delivered technical information with that of paper-based TMs in supporting the information needs of Navy technicians. A secondary purpose was to obtain information related to the implementation of the PEAM delivery concept from prospective users in the surface fleet.

Accordingly, a two-part approach was followed. The first, Comparative Assessment, involved both quantitative and qualitative assessments of the PEAM concept under controlled test conditions. The second, Implementation Issues, addressed issues and problem areas to be considered prior to the formal introduction of a PEAM-like device in the fleet.

PART I: COMPARATIVE ASSESSMENT

The technical objective of Part I was to test PEAM in an operational environment as a maintenance aid for the NATO SEASPARROW Surface Missile System (NSSMS). As initially planned, comparisons were to be made between PEAM and paper-based documentation in supporting both preventive and corrective maintenance activities on the NSSMS (see Appendix A). Several technical difficulties were encountered, however, in loading the NSSMS data base onto PEAM memory modules, which effectively precluded (1) use of the PEAM hardware and (2) data collection in a shipboard environment. Table 1 lists a chronology of the PEAM hardware and software difficulties encountered when attempting to load the NSSMS data base. As a result, two major modifications were made to the original test plan for the Navy evaluation of PEAM. The first was the use of alternative computer hardware for presenting the technical information contained in the NSSMS data base. The second was the elimination of the shipboard comparative assessment between PEAM and existing documentation that supported scheduled maintenance activities. The latter modification was required because the weight and bulk of the alternative computer did not allow it to be transported to NSSMS equipment sites aboard ships.

It should also be noted that, unlike the PEAM device, the computer hardware used to present the NSSMS data base did not have speech input or output capabilities. The utility of these capabilities, therefore, could not be assessed in the present effort. (See Schurman and Kincaid (1988) for a description of PEAM hardware use and data collection in an operational environment.)

Troubleshooting Problems and Administration

There were two troubleshooting problems defined by subject matter experts as representative of the types of problems encountered by NSSMS fleet technicians. Scenarios were then developed for each problem using a simulation technique developed by Connor (1987). The problems, which were simulated on a personal computer (PC), consisted of two NSSMS printed circuit card malfunctions--one affecting the firing officer console; the other, the director control unit.

At the start of each problem, the major casualty symptoms and operational discrepancies associated with the printed circuit card failure were displayed on the PC. This information was followed by the presentation of various menus from which technicians were expected to: (1) select a unit of the NSSMS to initiate troubleshooting actions, (2) specify a reference designation for individual test points, card pins, component parts, etc., to be checked, (3) choose a particular type of measurement (e.g., voltage, waveform, continuity) to be performed on a reference designation selected for testing, (4) troubleshoot the problem until such time as the failure was isolated to a suspected printed circuit card and component part, and (5) replace the suspected faulty printed circuit card to determine if that action corrected the malfunction. Figure 1 provides an example of the general structure of the various menus and data inputs used for troubleshooting.

Table 1

Summary of Problems Encountered, Corrective Actions Taken, and Time Delays Experienced when Attempting to Field an Operable PEAM Device

Problem	Corrective Action	Time Delay (duration)
1. All attempts to compile Navy PEAM data base were unsuccessful. More than 1000 software errors (e.g., misspellings, improper linkages, incorrect syntax) were identified; correction of these errors alone exceeded memory capacity for presentation on PEAM hardware.	Developed software tools and techniques to correct errors; resultant data base now well within limits for presentation on PEAM hardware.	90 Days
2. Revised data base was compiled successfully on SUN 3/75 computer workstation; however, attempts to download to PEAM hardware failed.	Inability to download data base probably resulted from errors in transfer utility. PEAM developer provided new copy of transfer utility.	60 Days
3. PEAM developer attempted to identify problems within data base and successfully compiled and downloaded a subset of the data base. Government downloading attempts continued to fail. Apparent problem involved computer hardware differences between government and PEAM developer.	Used Sun model 3/75 computer workstation to present Navy data base originally developed for PEAM hardware; revised test plan.	60 Days

Note. Approximately 7.5 months were spent in attempting to resolve difficulties with PEAM hardware and software.

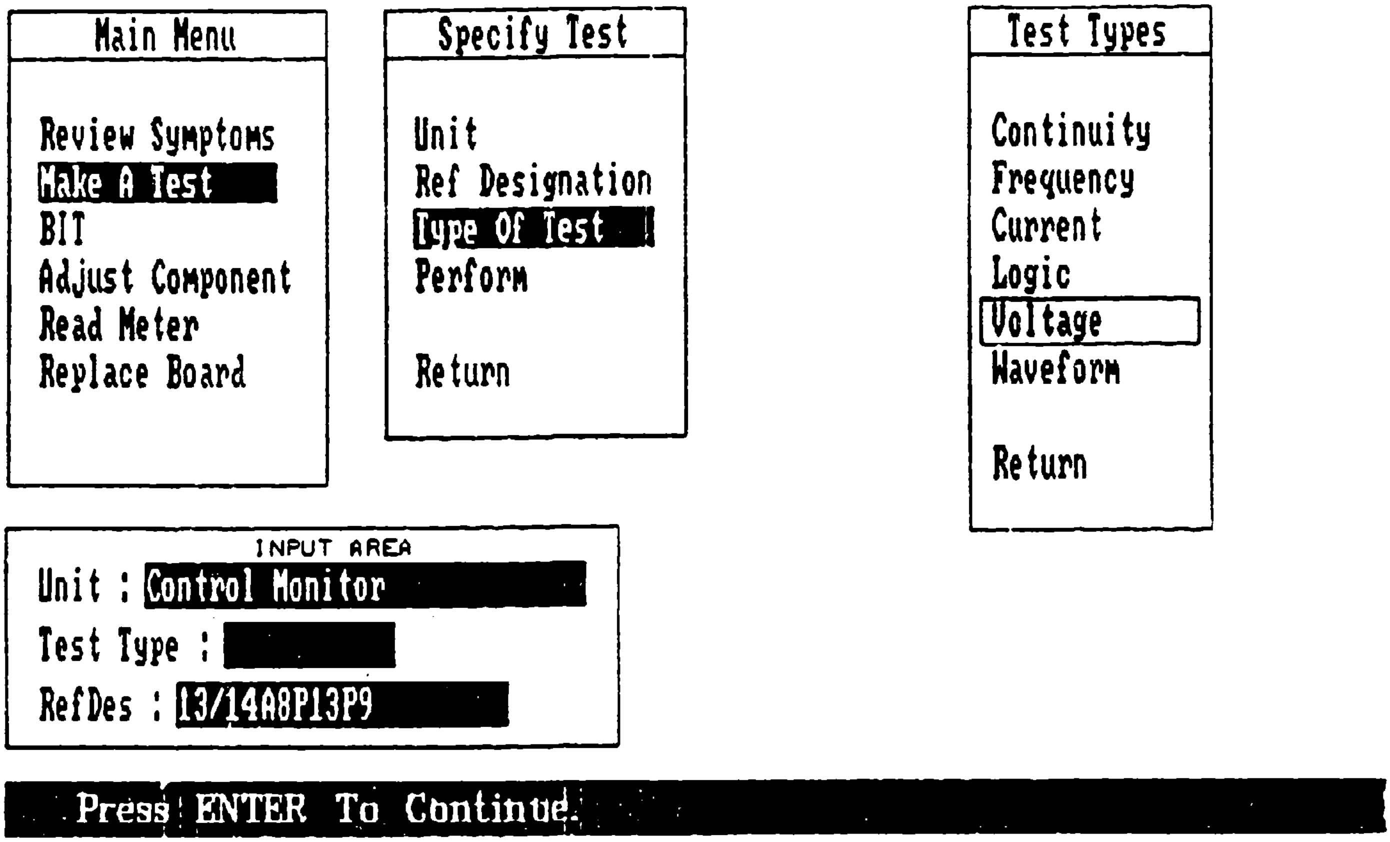


Figure 1. An example of the menus used to guide NSSMS troubleshooting tasks.

The simulation software also presented feedback information to the technician consisting of measurements obtained or waveforms present at particular test points, prompts for data inputs, and messages concerning the validity of various troubleshooting and repair actions performed. In addition, the computer was programmed to record data from the technician's troubleshooting performance.

Technical Information Delivery Systems

The two delivery methods used to present troubleshooting information were a Sun model 3/75 computer that contained the data base originally developed for PEAM, and standard TMs for the NSSMS MK57 Mods 2 and 3. The latter publications were all unclassified and consisted of more than 40 separate binders and 16,000 pages. With the exception of minor differences between the Sun computer and PEAM hardware in the method of accessing information (i.e., use of a mouse control versus pushbutton or voice activation of operator commands), the organization and format of the NSSMS data base were identical to that which would have been presented on the PEAM units.

To construct the automated data base for the NSSMS, information from the TM was first organized into a hierarchy of expected maintenance actions. This hierarchy was modeled after the troubleshooting strategy taught in the Navy's electrical and electronics training schools. That is, once a malfunction has been detected at the system level, the data base allows the technician to trace the symptoms of the malfunction through the subsystem, equipment, and component levels. In addition, branches to auxiliary types of technical information are provided at each level within the hierarchy.

Next, the order in which the technical information had to be stored in the computer was established and initial links among various elements in the data base were determined. Individual troubleshooting frames were then constructed from existing signal flow diagrams in which signal inputs and outputs were identified and linked either to previous or subsequent troubleshooting frames in the data base. Each troubleshooting frame also provided automatic links to supporting technical data (e.g., simplified signal flow diagrams, parts information, narrative descriptions of circuit functions and their interrelationships). Figure 2 illustrates how the signal flow diagrams were broken up into frames and how the input/output signals were linked to other frames. Figure 2 also shows how the different types of data were linked in the automated data base. Appendix B presents examples of the structure and format of actual frames that comprised the automated data base for the NSSMS.

This type of approach to the data base structure provides the flexibility necessary to go beyond electronic page turning. With linkages built into the data base, the user only has to decide what type of information is necessary. Branching is automatic. With paper, the user has to physically locate the desired information, a very time-consuming and frustrating process when the data base comprises several thousand pages of information. For example, when using TMs for one of the NSSMS troubleshooting scenarios, the technician had to:

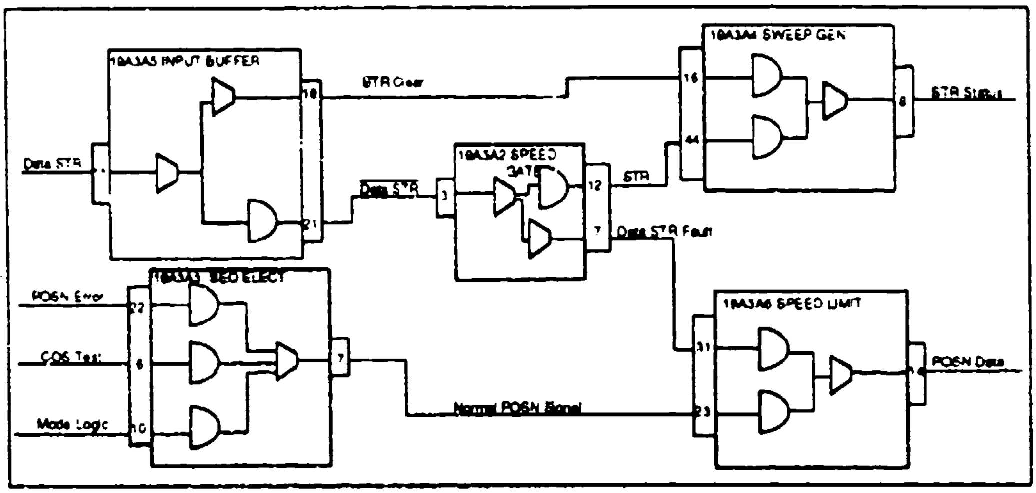
- start with a symptom table in one TM that referenced
- a second table (242 pages later) that referenced
- a third table (38 pages later) that referenced
- a different TM for a specific signal flow diagram that spanned 10 double-sized pages.

Collectively, there were 26 cross-references to needed technical information in the foregoing tables and diagrams.

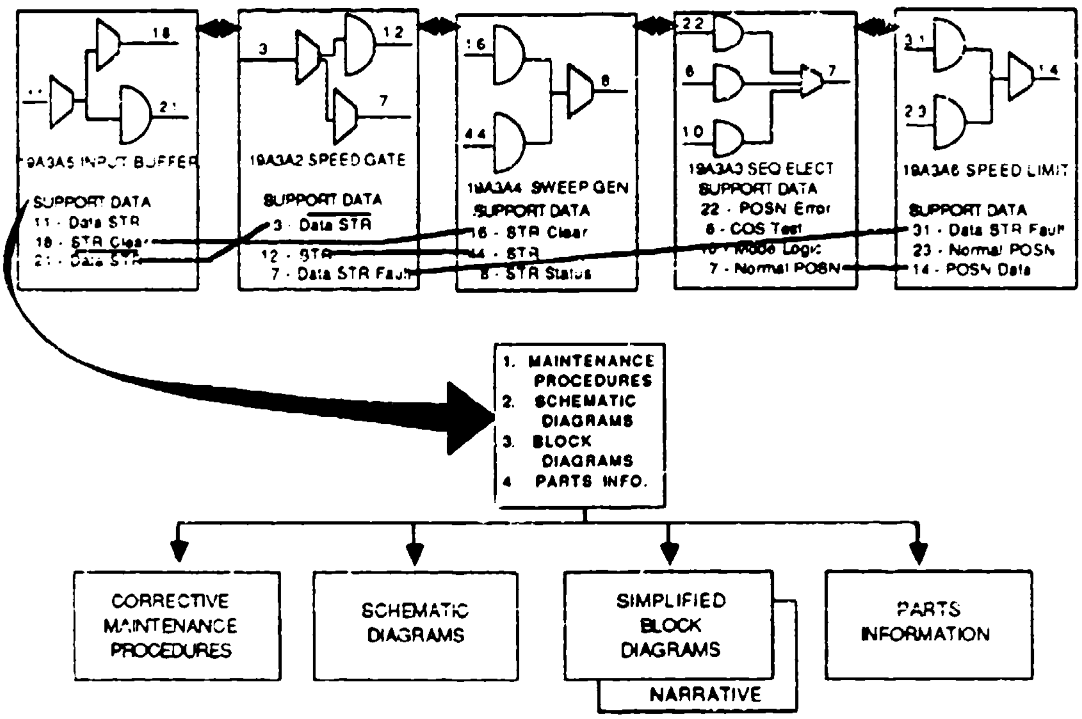
Test Participants

There were 28 participants in the study, consisting of 15 instructors and 7 students from the NSSMS class "C" maintenance training course at the Combat Systems Technical Schools Command in Mare Island, California, and 6 NSSMS technicians assigned to fleet units in San Diego, California. These participants were classified into two groups consisting of 20 experienced and 8 inexperienced technicians. These classifications were based on a combination of relevant field experience in the maintenance of the NSSMS (i.e., 1 or more years for the experienced group; less than 1 year for the inexperienced group) and judgments of immediate work supervisors concerning the technicians' maintenance work qualifications.

The decision to include maintenance experience as a factor in the present study was made for two reasons. First, it was the contention of the project team that any



(a)



(b)

Figure 2. An example of a signal flow diagram from the NSSMS technical manual (a), and how it was represented by separate frames in the automated presentation system (b). The lines and arrows in the bottom figure depict linkages of signal lines between frames or the types of support data available from any one frame.

computer-based technical information delivery system developed for military applications must be both useful to and usable by technicians of varying knowledge and skill levels. Second, several studies have shown that when evaluating job task proficiency, level of experience accounts for substantial variance in task performance (e.g., Brown, 1964; Goff, Schlesinger, & Parlog, 1969; Kieras, Tibbits, & Bovair, 1984; Nugent, 1988).

Participation in the testing was voluntary. No one declined to participate, and all technicians appeared to be interested and cooperative throughout the test sessions.

Procedure

A detailed test proctor's guide was developed to standardize the presentation of instructions, technical information delivery systems, and troubleshooting problems to all participants. The following sections summarize the procedures used in each test session.

Preliminary Instructions and Procedures

At the start of the session participants were assigned to groups of two, irrespective of their experience level. Instructions were then read aloud to the participants to provide them with a general orientation to the testing and data collection methods. Procedures for maintaining the technician's anonymity and voluntary participation in the testing were described, followed by a set of questions regarding each participant's background.

The participants then received instruction and practice on the basic operation of the computer hardware used to present the simulated troubleshooting problems and, similarly, for accessing technical information from the NSSMS data base. This training was followed by a general question-and-answer session during which time the participants were encouraged to request information and details for any procedures that may have been unclear to them. Upon completion of the preliminary instructions and procedures, which averaged 40 minutes, technicians were given a short rest break.

Problem Administration

The troubleshooting problems were administered individually to the participants at one of two workstations. One of these workstations contained standard maintenance publications for the NSSMS; the other, the automated NSSMS delivery system, that is, the Sun model 3/75 computer. Both workstations had a PC that hosted the simulation scenario for the NSSMS troubleshooting problems. Since the technical information needed to solve the troubleshooting problems was available at both workstations, each participant was randomly assigned one of the two problems. Combinations of problem presentation and delivery method were balanced to avoid experimental bias.

Before starting each problem, the test participants were informed that the test administrator at each workstation would only provide information to them regarding: (1) expiration of the time allowed for completing each problem, or (2) actions needed to extricate themselves from difficulties encountered when using either the PC or the Sun computer (i.e., for inputting data or accessing technical information, respectively). Upon completion of the first problem, participants were given a short rest break, after which they were directed to the other workstation for administration of the second troubleshooting problem.

Data Collection Forms

Two basic forms were used to collect performance and attitudinal data from the test participants.

Performance Observation Form. This form, which consisted of four sections, was completed by the test administrator at each workstation. Section I provided spaces for recording information regarding the technician's ability to locate and use correct reference material for initiating troubleshooting actions (e.g., fault directories and troubleshooting indices in NSSMS publications; equipment lists and fault menus in the automated NSSMS data base). Section II was used to record both general and highly specific information related to the test problems (e.g., the number, type, and validity of various tests and actions performed). Essentially, this section was designed to provide a "backup" record of the participant's performance data in the event that the automated performance monitoring software developed for the PC malfunctioned. Sections III and IV were used to record the technician's ability to locate parts data and descriptions of the physical and/or functional characteristics of the faulty printed circuit cards, respectively. As a minimum, all four sections of the performance observation form provided spaces for recording start and stop times, whether correct technical information was located and used, and observations or notes of the test administrator.

User Questionnaire. This form (shown in Appendix C) was administered to all test participants immediately after the second troubleshooting problem had been completed. It contained questions requiring participants to: (1) rate the physical features of the computer used to present the NSSMS data base, (2) rate the operation and software features of the automated presentation format, and (3) compare the automated presentation system with the paper TMs. A fourth section took the form of an open-ended question for recording any comments, complaints, or suggestions regarding the automated presentation system.

Debriefing

The test session, which lasted an average of 3 hours per technician, ended with a discussion of the purpose of the study together with a review of the participant's performance on the problems. The technicians were then thanked for participating and asked to refrain from discussing details of the study with others who had not yet been tested.

Experimental Hypotheses and Design

The following experimental hypotheses served as the framework for evaluating troubleshooting performance as a function of the technicians' experience level and the two methods of presenting technical information:

1. Total task time for troubleshooting will be less when the automated presentation system is used.

Troubleshooting using paper-based manuals typically requires the acquisition of information from various locations within a single manual or in two or more manuals. Simply "thumbing" through these manuals is highly time-consuming. The automated presentation permits virtually immediate access to any desired information and will reduce total task time.

2. Fewer errors will be made when the automated presentation system is used.

Use of technical information does not guarantee successful fault isolation. A critical factor in troubleshooting when using paper-based TMs is the necessity to refer to a specific line or item entry in a long list or complex diagram. The likelihood of the technician making a locational error leading to unsuccessful fault isolation or a false replacement is relatively high. (A false replacement is the identification and replacement of a component that was suspected as the cause of the problem but did not alter the original set of symptoms.) The automated presentation system, by displaying better organized technical information with easy access to additional support information, will increase successful fault isolation and decrease false replacements.

3. When using the automated presentation system, technicians will refer to technical information more and, subsequently, make fewer, more valid tests.

Technicians tend to employ shortcuts, presumably because of difficulty in accessing, understanding, and/or using technical information in its paper-based format. Since the automated presentation system provides ready access to all information in a more understandable and usable form, technicians will avoid shortcut approaches and make more use of available information when using the automated presentation system. Thus, there will be fewer tests and the selection and execution of tests will be more appropriate (i.e., valid) for systematically and conclusively isolating the fault.

4. Inexperienced technicians using the automated presentation system will troubleshoot as well as experienced technicians using TMs.

In other words, the advantages of the automated presentation system will counterbalance experience advantages when comparing inexperienced technicians using the automated system with experienced technicians using paper TMs.

5. When comparing performance within each technical information delivery system, experienced technicians will troubleshoot better than inexperienced technicians.

On a composite grading system that includes time, errors, etc., it is expected that experienced technicians will outperform inexperienced technicians within each information delivery system, due to their more thorough exposure to and working knowledge of NSSMS maintenance.

The independent variables of technician experience level, technical information presentation method, and NSSMS troubleshooting problems were arranged in a 2 X 2 X 2, mixed design. While a technician's experience level was fixed, all participants used both presentation methods. Combinations of troubleshooting problem and presentation method were balanced to avoid experimental bias. The dependent measures were:

1. Number of out-of-bound errors--an incorrect deduction that the testing of one or more printed circuit cards would provide useful information for isolating the failure when, in fact, the card selected for testing was functioning properly and was not contained within the boundaries of the fault path.

2. Number of valid checks performed--the selection of an appropriate electrical or electronic measurement technique for a particular test point, card pin, component part, etc.

3. Number of invalid checks performed--the selection of an inappropriate electrical or electronic measurement technique; for example, attempting to measure the frequency of a resistor.

4. Number of proof points checked (i.e., the number of possible input and output points tested in the faulty circuit that conclusively isolates the fault).

5. Number of false replacements recommended to correct the failure--a technician's recommendation for replacing one or more printed circuit cards that were functioning properly and would not correct the fault condition.

6. Total number of fault isolation tests performed.

7. Overall time to problem completion.

8. Success or failure in isolating the faulty printed circuit cards.

9. Time to initiate specific troubleshooting actions, that is, the elapsed time from the receipt of the equipment failure symptoms to the participant's first use of either the TMs or the automated presentation system.

10. Success in locating appropriate diagnostic/troubleshooting information in either the TM or the automated presentation system.

11. Time to locate parts information for faulty printed circuit cards.

12. Success in locating the parts information for faulty printed circuit cards.

13. Time to locate narrative information describing the physical and/or functional characteristics of faulty printed circuit cards.

14. Success in locating narrative information describing the physical and/or functional characteristics of faulty printed circuit cards.

Dependent measures 1-8 were categorized as those related to troubleshooting, while measures 9-14 were categorized as those related to information location.

Results

Demographic Comparisons

Prior to conducting tests of the experimental hypotheses, the authors conducted analyses to determine the extent to which the two groups of test participants differed with respect to items contained on the personal background form. These analyses were performed to provide quantitative evidence that the two groups did differ on variables related to the experience level. Accordingly, a multiple analysis of variance (MANOVA) was used to compare the two groups on the basis of: (1) current enlisted pay grade, (2) months of maintenance experience on the NSSMS, and (3) number of enlisted occupational specialties held.

Results showed that the two groups differed significantly ($p < .01$ in all cases) on the above variables: The experienced technicians had a higher average enlisted pay grade (5.7 versus 3.6), more months of NSSMS maintenance experience (41.7 versus 4.0), and held more enlisted occupational specialities (1.6 versus 0.3) than the inexperienced group.

Performance Analyses

Since the first 8 dependent measures were categorized as troubleshooting measures and the remaining 6 as information location measures, two separate analyses were performed, one for each category.

Because 8 of the 28 participants failed to solve one of the two troubleshooting problems administered when using NSSMS technical manuals, no data were collected from those 8 with respect to the information location measures. For each of the 8, the troubleshooting session was terminated due to the time criterion established by subject matter experts. (A 1-hour time limit was allowed for isolating the failure to the printed circuit card level. If this criterion was met, an additional 15-minute period was allowed to isolate to the component level; otherwise the session was terminated.) Thus, the results are presented in two ways--the 8 troubleshooting measures for all 28 participants and the troubleshooting and information location measures for the reduced sample of 20 participants.

Overall Sample

As shown in Table 2, a statistically significant multivariate F-ratio was obtained for the presentation method/troubleshooting problem interaction ($F(8, 41) = 4.80$, $p < 0.01$). Based on this interaction, MANOVAs were computed to determine the effect of the presentation method on each troubleshooting problem. Results from these analyses showed a significant multivariate F-ratio for the firing officer console problem ($F(8, 19) = 9.71$, $p < .01$), but a nonsignificant F-ratio for the director control problem ($F(8, 19) = 1.53$, $p < 0.22$). This finding led to an examination of the univariate F-ratios to identify the specific variables on which the two presentation methods differed with respect to the firing officer console problem. Table 3 provides a detailed breakdown of these performance differences.

Table 2

MANOVA Results for Overall Sample
($N = 56$)[a]

Part I: Multivariate tests with 8, 41 degrees of freedom (df).

Unit of Analysis	F	p
Experience x Mode x Problem	1.09	.39
Mode x Problem	4.80	.01
Experience x Problem	0.48	.86
Experience x Mode	0.95	.48
Problem	9.10	.01
Mode	5.51	.01
Experience	0.89	.53

[a]Since the NSSMS troubleshooting problems were treated as an independent variable in this MANOVA design, 56 observations were included in the analysis (i.e., 28 participants x 2 problems each).

Table 3

Performance Comparisons for the Overall Sample
Concerning the Firing Officer Console Problem
(N = 28)

Measure	M Technical Manual	M Automated Presentation	$F(1, 26)$	p
Time-to-condition (mins.)	58.5	34.8	38.59	.01
Problems solved (%)	53.0	100.0	10.56	.01
Test points checked	9.1	8.3	0.42	.63
False replacements	0.8	0.0	14.04	.01
Out-of-bounds errors	6.3	0.4	28.48	.01
Valid checks	8.7	8.2	0.09	.77
Invalid checks	1.9	0.08	12.43	.01
Proof points	0.9	2.0	19.82	.01

Significant differences were found between the two technical information delivery methods with respect to: (1) the overall time to problem completion, (2) the number of false replacements recommended to correct the failure, and (3) success in isolating the problem to the faulty printed circuit card; thereby supporting the predictions of the first and second experimental hypotheses, respectively. Although no difference was found between the two presentation methods regarding the total number of fault isolation tests performed, significant differences were found for all but one of the remaining dependent variables used to assess the validity of those tests. That is, technicians who used TMs for the NSSMS made significantly more errors (i.e., out-of-bounds and invalid checks) and checked significantly fewer proof points than those using the automated presentation system. This finding supports the third hypothesis.

Contrary to the predictions concerning the participants' experience level and presentation method (i.e., hypotheses 4 and 5), no significant interaction was found between these factors for the 8 troubleshooting measures (Table 2). There was a significant interaction, however, between experience and presentation method for the 6 information location measures, which is described in the next section.

Reduced Sample

Results from the 20 participants who were successful were analyzed separately. The results from the multivariate analysis of 7 of the 8 troubleshooting measures for the reduced sample mirrored the previous analysis. (The dichotomous "pass" or "fail" score was excluded from the latter analysis since this measure had no variance.) There was a significant interaction between troubleshooting problem and presentation method. As in the analysis for the overall sample, no difference between the two presentation methods with respect to the director control unit problem was found. Accordingly, Table 4 presents the performance differences attributed to the presentation method factor for the firing officer console problem.

Table 4

Performance Comparisons for the Reduced Sample
Concerning the Firing Officer Console Problem
(N = 20)

Measure	M Technical Manual	M Automated Presentation	$F(1, 19)$	p
Time-to-condition (mins.)	56.6	34.8	18.10	.01
Test points checked	10.6	8.3	2.42	.14
False replacements	0.8	0.0	15.12	.01
Out-of-bounds errors	4.6	0.4	26.88	.01
Valid checks	10.5	8.2	1.97	.18
Invalid checks	2.4	0.08	20.03	.01
Proof points	1.6	2.0	7.06	.05

With regard to the remaining 6 dependent measures (the information location measures), MANOVA results (summarized in Table 5) showed significant interactions for experience level and presentation method ($F(6, 35) = 3.25$, $p < .05$) and for the troubleshooting problem and presentation method ($F(6, 35) = 2.55$, $p < .05$). For each of these interactions, only a single dependent variable differed reliably at the univariate level of analysis: success in locating narrative descriptions of the faulty circuitry for the first interaction effect; time to locate parts information for the second. More specifically, results showed that: (1) all technicians who used the automated presentation system were successful in locating appropriate narrative information, compared to 71 percent of the experienced and 33 percent of the inexperienced technicians who used TMs, and (2) technicians who used the automated presentation system took significantly less time to locate parts information for both the firing officer console and director problems (M = 1.07 and 1.13 minutes, respectively), compared with technicians who used TMs (M = 4.9 and 8.7 minutes for the firing officer console and director problems, respectively).

User Evaluation Questionnaire

The results from the 25 items in the User Evaluation Questionnaire (Appendix C) are shown in Table 6. Each question had a 5-point scale ranging from 1 (unsatisfactory or significantly less) to 5 (outstanding or significantly more). Overall, the NSSMS technicians rated the automated presentation system from 3 (satisfactory) to 4 (highly satisfactory). Although various physical characteristics were assessed in the first 10 questionnaire items, a single mean (3.59) is shown for these items to reflect the similarity in the ratings assigned to those characteristics. Similarly, the technicians rated the adequacy of the computer operation and software features in the "satisfactory" to "highly satisfactory" range (M = 3.74). Use of the automated system was also perceived by the technicians as an improvement over TMs for the NSSMS in terms of efficiency and effectiveness in providing needed maintenance information. In addition, no differences were found between the ratings of experienced and inexperienced technicians relative to the four main categories of questionnaire items.

Table 5

MANOVA Results for Reduced Sample on Supplemental Performance Measures (N = 48)[a]

Part I: Multivariate tests with 5, 35 degrees of freedom (df).

Unit of Analysis	F	p
Experience x Mode x Problem	2.02	.09
Mode x Problem	3.24	.05
Experience x Problem	0.56	.76
Experience x Mode	2.55	.05
Problem	3.51	.01
Mode	22.87	.01
Experience	2.38	.05

[a]Supplementary performance data were not obtained for the 8 technicians who failed to solve the NSSMS troubleshooting problems when using technical manuals (TMs).

Table 6

Summary of User Evaluation Questionnaire (N = 28)

Feature	Questionnaire Items	M
Physical features	1-10	3.59
Operation & software features	11-17	3.74
Accessing information problems	18-20	2.48
Effectiveness of information	21-25	3.97

Scale Values:

Questions 1-17: 1 = unsatisfactory; 5 = outstanding.

Questions 18-25: 1 = significantly less; 5 = significantly more.

(Low values for Questions 18-20 reflect a positive response.)

A review of the open-ended comments found that the technicians' overall impression of the electronic delivery system was generally favorable. The primary criticism concerned the size of the display screen for presenting schematic-type diagrams, that is, the diagrams were too small, thus precluding a view of them in their entirety.

PART II: IMPLEMENTATION ISSUES

The technical objective of Part II was to obtain information related to fleet implementation of an automated presentation system, such as PEAM. The implementation issues addressed included: (1) assessing the user's (the NSSMS technician) needs for an automated presentation system, (2) identifying logistical support considerations, (3) determining training implications, and (4) identifying interfaces with other automated shipboard data bases. As noted in Part I, hardware and software problems precluded the use of an operable PEAM device. Thus, data collected during this part of the evaluation were based more on a conceptual narrative description of an automated presentation system than on an operable prototype.

Participants

Information was collected from two different groups of personnel. One group consisted of 25 enlisted NSSMS technicians who completed a structured questionnaire (shown in Appendix D). Each technician in the sample had a minimum of 6 months' fleet experience in troubleshooting NSSMS. Fourteen technicians were from SPRUANCE-class destroyers (DD 963) and 11 were from aircraft carriers (CV). The mean time these technicians had served as fire control technicians was 3.2 years, with a range from 1 to 9 years. The mean time they served as NSSMS technicians was 1.5 years, with a range from 8 months to 7 years.

There were nine in the second group: seven NSSMS "C" school instructors, an NSSMS documentation expert, and the project director for the development of an automated data base for the MK 15 (PHALANX) Close-In Weapon System.

Method

Technicians in the first group were told that the Navy and the other services were investigating the feasibility of transitioning from paper-based TMs to an automated presentation system for maintenance information. PEAM was described as one example of how the automated presentation system concept might be accomplished. During the presentation of the PEAM concept, the technicians had an opportunity to ask questions. They then completed the questionnaire.

For the second group, open-ended interview questions were used. An orientation was given about the possible transition from paper TMs to an automated presentation system. Each participant was asked to reflect on the work they were doing and how this transition might impact on that work. Specifically, the "C" school instructors were asked about the impact on the training of NSSMS technicians; the NSSMS documentation expert was asked to consider how the implementation of a device such as a PEAM could impact his work in the development of technical documentation; and the project director was asked to talk about his experience related to the development of an automated data base.

Results

The questionnaire data from the 25 technicians are given in Appendix D. A summary of these data along with the information from the open-ended interview questions pertinent to each area of consideration is provided below.

User Considerations

All but one technician thought that two or three PEAM devices would be needed to maintain a single NSSMS system. The rationale was that since NSSMS consists of multi components distributed throughout the ship, it would be convenient to have a PEAM device placed at more than one decentralized location, as simultaneous maintenance activities are sometimes required on NSSMS components, and multiple devices per NSSMS would provide backup capability if one became inoperative. Most of the technicians also preferred that the PEAM memory modules be co-located with each PEAM if more than one set of modules was provided. If, on the other hand, only one set of memory modules was provided per NSSMS, most of the technicians preferred decentralized storage locations for the PEAM devices with the memory modules distributed to each device location. The primary reasons were convenience and survivability.

The majority of technicians preferred a functional organization of the maintenance information in the automated presentation system. This would match the current organization of the TMs, which eliminates the need to search for each unit. The functional approach was also preferred for labeling the memory modules.

The project director indicated that a key task will be to design an index or indices that will allow the technician to access information as quickly as possible. Most of the technicians preferred a table of contents-type of indexing located on one memory module.

One of the NSSMS instructors suggested that PEAM have a marking system so that a technician could "mark" the place being used if called away to perform a collateral duty. It would then be possible for the technician to quickly return to the information accessed previously, even though another technician may have used the same module in the interim.

Logistical Support Considerations

The technicians were evenly divided on where updating and correcting of PEAM memory modules should take place. Reasons supporting shipboard updating included efficiency, accountability, and the fact that the technician would be aware of what information needed revision. Updating at shore-base commands, on the other hand, is better for quality control and standardization. It was also mentioned that fleet technicians might inadvertently erase or damage the contents of the modules during the updating or correction process.

Because of potential damage to or loss of memory modules from a variety of causes, most of the technicians preferred a shipboard capacity for producing backup copies. This arrangement was thought to be more efficient and would also save paperwork. About half the technicians thought that damage or degradation of the modules could occur from transmitter emissions or when PEAM was used near the NSSMS launcher or director. Damage to the PEAM device and memory modules might also result from exposure to water, high temperatures, dust, and other airborne particulate matter.

The NSSMS documentation expert stated that the development of a technical information data base involves a variety of participants in both the government and private sectors. With current paper TMs, there is the time-consuming process of sending examples and copies of materials from the TM originator to the approving agency and vice versa. The documentation expert felt that the use of an automated system would render the development process more efficient. All participants could view the same information simultaneously and make any necessary additions and corrections instantaneously. The updating process will also be more efficient for both the agency responsible for making changes and for the technician. Currently, the revised pages are mailed to the appropriate work center aboard ship where the technical manuals are stored. A technician in the work center must then remove the affected pages from the TM and insert the pages with the updated information. With the use of an automated system, the technician would most likely update the technical information system electronically, by means of a magnetic tape, diskette, or optical disc containing all the relevant changes.

The technicians preferred that they be responsible for maintenance of the PEAM device. They also preferred that the maintenance information for the automated presentation system itself take the form of planned maintenance system cards or a paper TM.

Most of the technicians cited situations and/or conditions that would require a paper copy of information contained in PEAM memory modules. For example, two or more technicians could produce paper copies of selected portions of a memory module, then take that information to various equipment sites aboard ship. The NSSMS computer room was the preferred shipboard location for a printer. While a printer was preferred, more than half the technicians perceived problems, such as having responsibility for maintaining the printer and ordering supplies for it.

Training Considerations

It was felt that training in the use of PEAM would most likely occur either in the technical training schools or in the fleet. Most of the technicians indicated that the extant NSSMS "C" school would be the best place for preliminary training in the operation of an automated presentation system. For those technicians who do not receive training on PEAM in "C" school, an on line demonstration and instruction book should be made available aboard ship.

The importance of shipboard training was emphasized by one of the NSSMS "C" school instructors who noted that when new technicians report aboard ship, they very often do not have an opportunity to engage in troubleshooting for 6 to 12 months. When they do begin to troubleshoot, much of the information learned concerning the organization of the TMs has to be relearned. A TM refresher course could be built into the automated presentation system.

Responses from the "C" school instructors suggest that NSSMS maintenance training courses could be enhanced with feedback from the fleet on troubleshooting experiences. For example, the automated presentation system (PEAM) could be programmed to capture the troubleshooting strategies used by NSSMS technicians. This information might include such factors as: symptom recognition and elaboration, amount and type of technical information accessed, test points checked, and proposed solutions. From these data, scenarios could be developed into case studies for use by the technical training schools.

Although a variety of training applications were identified for PEAM, there was little consensus among the technicians as to any one specific application. Nevertheless, it was felt that PEAM could be useful for providing training in the areas of general damage control, general maintenance, and the use of fire fighting equipment.

Interface Considerations

The technicians thought that PEAM could be expanded for use as an automated fault diagnostic aid. This could take the form of a stand-alone device to which equipment casualty symptoms would be inputted for resolution through its expert reasoning capability. Alternatively, an automated presentation system with diagnostic capability could interface with built-in automatic test equipment currently used to support NSSMS diagnostics. Suggestions were also made for providing the automated presentation system with a capability to automate certain shipboard maintenance support functions that are currently performed manually, such as preparing equipment casualty reports and documenting planned or completed preventive maintenance activities.

DISCUSSION

The results of this comparative assessment of paper-based and computer-based maintenance information delivery systems are discussed in terms of (1) effect on performance, (2) implementation issues, and (3) impact of innovative changes on the Navy's personnel subsystem.

Effect on Performance

Results from this study showed that the use of electronically delivered technical information during troubleshooting was more effective than the use of paper-based TMs. The degree of effectiveness, however, was related to troubleshooting complexity. While it had been the initial intent to use two troubleshooting problems of comparable difficulty, it became apparent in the analyses of the resultant performance data that the two problems were, indeed, different. The firing officer console problem represented a considerably more difficult troubleshooting task than the director control unit problem. As such, no significant differences in performance were observed for the director control unit problem regardless of presentation method. Thus, the payoff in effectiveness for electronically delivered technical information appears to be in accomplishing the more complex troubleshooting tasks, such as those represented by the firing officer console problem.

When technicians were asked to troubleshoot the firing officer console problem, use of the automated presentation system resulted in a 60 percent reduction in total troubleshooting time. More importantly, there was a 100 percent success rate in fault isolation compared with a 53 percent rate for those using the paper-based TMs. (There was a 100% success rate with the automated presentation system for the director control problem as well, although the success rate using TMs was also high, 92%.) There were no false replacements in troubleshooting the firing officer console when using the automated presentation system, while the average when using TMs was slightly less than one false replacement (0.70). Other error measure comparisons for the firing officer console problem also supported the effectiveness of the automated presentation system: Technicians checked twice as many proof points and were 12 times less likely to commit an out-of-bounds error.

These data suggest that savings of more than one kind are possible. For example, current field data for the NSSMS indicate that the mean-time-to-repair (MTTR) for the firing officer console is 8.1 hours. The 40 percent reduction in troubleshooting time obtained from the present study would reduce the MTTR for the firing officer console to approximately 4.9 hours. Field data also provide a measure related to false replacements, viz, no evidence of failure (NEOF). The firing officer console NEOF rate for a 12-month period in 1986 was 9. This value is close to the 11 false replacements made by the participants who used the paper TMs in the present study. Switching to an automated presentation system has the potential for reducing the firing officer console NEOF rate to zero.

The automated presentation system also dramatically improved the technicians' ability to reference only the information needed to isolate equipment faults. When the technicians used the automated presentation system they performed fewer tests (a ratio of 1:1.3) and had fewer invalid checks (a ratio of 1:3) compared with when they used the TM. By providing a more efficient way of accessing technical information, the automated presentation system should help maintenance technicians become more effective in less time when isolating equipment faults.

Although there was an expectation that the maintenance experience of the technicians would have a differential effect across all dependent measures, there was only a single measure in which there was a difference between inexperienced and experienced technicians. Specifically, there was a difference only when the participants were asked to locate narrative information for the two faulty printed circuit cards. When using the TMs, the experienced group had a higher success rate (71%) in locating the appropriate narrative information than the inexperienced group (33%). This finding is in sharp contrast to the 100 percent success rate for both the experienced and inexperienced technicians who used the automated presentation system. Thus, it appears that the automated presentation system offers a distinct advantage for inexperienced technicians in locating supplementary maintenance information.

Results from the questionnaire indicate that the technicians favor an automated presentation system for accessing NSSMS technical information. In addition, the technicians pointed out specific areas that they believed improved performance, and areas they felt needed to be improved. Examples of favorable comments were: "Information was available faster, at the press of a button," and "I did not have to flip through pages and change from one paper volume to another, since branching to another 'frame/page' of information with the computer was automatic."

Since screen size was limited, technicians had some difficulty relating to signal flow information that had to be sectioned in accordance with the physical size of the computer frame. The technicians were used to viewing 11 x 17-inch pages in TMs for that type of information. With the 5 x 7-inch display area of the automated presentation system, the technicians experienced some difficulty in maintaining an overall perspective of how the circuit components were linked together. Therefore, the technicians suggested that a windowing or scrolling capability be provided to allow concurrent viewing of signal inputs and outputs located on adjacent pages/frames. Such comments are interesting in that the technicians appear to recognize that an exact electronic duplicate of the 11 x 17-inch page from the TM would not be required. Windowing could also be used to allow viewing the signal flow diagram of interest while opening a window for other technical information, such as narrative text or other test points.

The performance data and the questionnaire responses from the present study are also supported by findings conducted by the Air Force, Army, and Navy.

In an Air Force study (Clay, 1986), a prototype computer-based maintenance aid system (CMAS) was developed to evaluate technical data presentation and user interface techniques. An off-the-shelf computer was used as the prototype delivery device. Software was developed to store and present technical information in an integrated text-graphics format. The technical information supported the RT-728A/APX-64(V) radio receiver transmitter. An evaluation of CMAS was accomplished by having technicians perform adjustment and alignment tasks using the technical information presented via CMAS. Eight technicians completed the assigned maintenance tasks and data were collected on the technicians' task times and attitudes toward CMAS. In general, the technicians expressed positive comments about the use of CMAS to support maintenance. Since the primary purpose of the CMAS study was only to demonstrate the concept of electronic delivery of technical information, only limited data comparing fault isolation using CMAS with the conventional paper technical manual were collected.

In a follow-on to CMAS, the Navy (Nugent, Sander, Johnson, & Smillie, 1987) compared troubleshooting performance using electronically presented technical information with that using standard TMs. The technical information was for the same equipment as the Air Force study, the RT-728A/APX-64(V) radio receiver transmitter. Thirty-six technicians in the Navy, Marines, and Air Force participated and attempted to isolate two printed circuit card failures using the technical information contained in an automated presentation system and two other failures when using paper TMs. All faults were found when the automated system was used, whereas there were nine occurrences where technicians failed to isolate one or both of the faults when using the TMs. With the automated presentation, technicians isolated faults in about one-half the time and made no false replacements.

In two Navy Technical Information Presentation Program (NTIPP) studies, maintenance performance was compared when technicians used either the standard paper TMs, reformatted paper TMs, or an automated presentation system. In the first NTIPP study, which involved the F-14A Rudder Control System, 24 technicians used one of the three formats for non-troubleshooting tasks (e.g., remove/replace) and either the standard paper TMs or the automated system for a troubleshooting task (Fuller, Post, & Mavor, 1987). Employing a somewhat unbalanced design, the authors found no apparent performance differences among the three formats for supporting non-troubleshooting tasks. There was, however, an improvement in success rate for troubleshooting tasks when using an automated system. All technicians who used the automated system found the fault, compared with seven technicians who failed to find it when using the standard paper TMs. Regardless of the performance data outcome, all but one of the participants favored automatic presentation over the paper TM.

A similar design was employed in the second NTIPP study (Fuller, LeBeau, Mavor, Post, & Sawyer, 1987). Twenty-four technicians were tested using technical information that supported the SPA-25D radar system. Results suggested that troubleshooting performance time can be reduced by approximately 24 percent when using an automated system. In addition, the majority of the technicians (22 of the 24) preferred the automated system overall, found the automated presentation easier to use, and said the data base for the automated system was better organized.

In an Army study (Department of the Army, 1987), the use of an interactive video disc was compared with that of paper TMs to perform maintenance tasks. Ten two-person operator-maintainer teams performed 302 tasks (i.e., fault isolation, remove and install, repair and verify, preventive maintenance, operation, and repair parts identification) on the PATRIOT Missile System. Half used the interactive video and half used the paper TMs. Although there were no differences in performance between the two presentation methods, all but one technician favored the electronic presentation over the paper TM.

Taken together, results from the foregoing studies demonstrate the potential benefits of automating the presentation of technical information. In general, data from these studies along with data from the present study show how maintenance performance might be improved with respect to such factors as success in fault isolation, time to complete maintenance tasks, and reduced error rates.

Implementation Issues

Although the present study was oriented primarily toward a specific application of an automated technical information presentation system, results from Part II of the present effort highlighted concerns that must be addressed prior to fleet implementation of a PEAM-like device.

To ensure adequate coverage and availability, multiple delivery devices and several copies of the data base are necessary. Equally important is distribution of the delivery devices throughout the platform the weapons support. Backup copies of the automated technical information data base are a necessity for shipboard applications. It also seems worthwhile to ensure compatibility between other computer-based delivery devices and software so that technical information designed for one device can be readily accessed from another, if necessary.

Transition from a paper to an electronic medium for authoring and storing technical information should make the development cycle for technical information more efficient, in particular the review and evaluation phases. In addition, revisions and updates should be faster and easier to incorporate and distribute, most likely as completely revised "manual sets." Thus, the time-consuming, error-prone task of page replacement/deletion will be eliminated.

Two issues must be addressed relative to personnel training. First, there is a need for training in the operation of the automated presentation system itself. While the necessary training should be simple and straightforward, the training should be integrated into the system training courses at the technical schools. Second, the automated presentation system can serve as a vehicle for both on-the-job training and participatory shipboard training. As such, technicians could use the automated presentation system to acquire new skills and knowledge related to the particular weapon system or to access other types of training (e.g., damage control, the planned maintenance system, personnel qualification standards).

The power and advantages of an automated presentation system will not be fully realized if the system is restricted to a single interface, that is, between the technician and the technical information data base. Since most advanced weapon systems in the Navy contain built-in test (BIT) capabilities, consideration should be given to developing an interface that would allow the automated presentation system to initiate BIT routines and process BIT data directly. Such an interface would eliminate the need for the technician to initiate BIT and then input the test results for subsequent evaluation by the system. An automated system equipped with an "expert reasoning" capability could evaluate the BIT results and provide the technician with a menu of alternative, most likely, next actions to perform; thereby minimizing the role of the technician as a data transfer agent and maximizing that person as an analytic decision maker. Interfaces with other shipboard data bases should be considered, such as the shipboard non-tactical ADP program (SNAP), the consolidated automatic support system (CASS), etc., to provide maximum usage of available maintenance data and to simplify parts ordering and documentation of maintenance actions.

Innovation Changes

As with any innovation, personnel issues must be considered. The primary emphasis in the design and development of any technical information delivery system should focus on the end user, in this case, a Navy maintenance technician.

With paper TMs, technicians have considerable latitude to formulate their own fault isolation strategy based on the symptoms of the fault. Thus, an experienced technician's repository of maintenance skill and knowledge may be based on the way in which information is organized within the TM. Inexperienced technicians, on the other hand, may not be able to quickly locate needed technical information from the TM. As the technician gains experience, however, he or she gradually develops more efficient ways of accessing that information. With an electronic presentation system, there may be the tendency on behalf of designers to capitalize on efficiency by directing the users along a predefined path, regardless of their experience. A question arises, then, in terms of direction. Should more reliance be placed on the automated presentation system to automatically display the most efficient and effective ways of using technical information? Or, alternatively, should the technician develop, through experience, the skill and knowledge necessary to access all relevant information about a maintenance problem? It appears that some type of compromise must be struck by the system designers, one in which the technician can either follow a predefined path or access the information according to personal preference (as the technician gains experience and knowledge).

A related issue concerns supervisors' perceptions of automated presentation systems. Will the use of such a system lead to higher expectations of efficiency without regard to the human-machine interface requirement? Probably, the most important issue is related to career advancement, that is, will there be well-defined career paths for technicians using an "automated" device? or will there be an attempt to eliminate the human-in-the-loop altogether? or will there be a move to settle for technicians with lesser skills? Complete reliance on an automated delivery system will very likely result in a complete dependence on that system. Although the exact role of the technician may change in the future compared with that of a technician who has been on the same job for 20 years, consideration must still be given to providing technicians with the capability to initiate other fault isolation strategies when the automated approaches fail. While career structure is primarily a social/policy issue, maximum effectiveness of any automated technical information presentation system depends heavily on its integration into the Navy's personnel subsystem, heretofore a factor that has not been adequately addressed.

CONCLUSIONS

Based on the first part of the evaluation, troubleshooting performance was improved when the automated presentation system was used to display troubleshooting information for the NATO SEASPARROW Surface Missile System. Specifically:

1. The more difficult the problem, the more effective the automated presentation system.

2. Use of the automated presentation system led to significant reductions in troubleshooting time (up to 40%) and error rates (fewer false replacements and fewer unnecessary tests), while at the same time resulting in 100 percent success rate for fault isolation.

3. Regardless of experience level, technicians were more successful and took less time locating additional information when using the automated presentation system.

4. Technicians preferred an automated presentation system over paper-based TMs.

Based on the second part of the evaluation, the authors conclude that the transition from a paper to electronic medium for presentation of technical information will have a major impact on the Navy's personnel subsystem in two important respects: (1) the way in which technicians interact with technical information contained in the automated data base, and (2) the changing role of maintenance technicians as they become fully or even partially supported by an automated presentation system. The authors also conclude that for shipboard maintenance applications, the automated presentation system must be available at dispersed locations to ensure access and survivability.

Finally, it should be noted that the Office of the Secretary of Defense established the Computer Aided Logistics Support (CALS) initiative in September 1985. A major purpose of CALS is to apply existing and emerging computer technology to automate the development, delivery, and maintenance of logistic and technical information across all branches of the Armed Forces. Among the major objectives recommended to support CALS are "extensive study of user interaction with non-paper maintenance aids" and "research, experimentation, and field trial experience to find out what forms of displays are best for specific situations" (Riddell, Gunkel, Beiser, Goldstein, & Lepisto, 1985). Although initiated prior to the establishment of CALS, the present evaluation does, in large part, address these objectives.

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APPENDIX A

EXTRACT FROM NAVY TEST PLAN FOR EVALUATING THE PERSONAL ELECTRONIC AID FOR MAINTENANCE (PEAM): EXECUTIVE SUMMARY

PURPOSE

The primary purpose of this effort is to compare the efficiency and effectiveness of an electronically delivered technical information system with that of a paper-based documentation system in supporting the information needs of maintenance technicians. This effort will also address issues related to fleet implementation and acceptance of the PEAM device. Accordingly, the test plan consists of two parts: (1) performance evaluations based on both preventive and corrective maintenance activities and (2) assessment of fleet implementation considerations. Specifically, PEAM will be compared with the existing paper-based documentation for the NATO SEASPARROW Surface Missile System (NSSMS).

PART I: PERFORMANCE EVALUATION

Proceduralized information provided by the maintenance requirement cards (MRCs) is usually not available to support complex problems affecting Navy hardware such as multiple faults or cascading or intermittent failures. When attempting to troubleshoot and correct system failures, Navy technicians often must consult and cross-reference maintenance information contained in the various volumes of the ordnance publications (OPs). These factors make hard-copy technical documentation use difficult, confusing, and error-prone.

Objective

The objective of Part I is to compare the effectiveness and efficiency of presenting maintenance information by means of PEAM with that of existing paper-based documentation in supporting (1) the performance of procedural maintenance on the NSSMS in a fleet environment and (2) the detection and isolation of faults which adversely affect normal NSSMS operations.

Task Description

Two types of maintenance tasks will be used in the evaluation: (1) procedural tasks, which consist of a series of regularly scheduled equipment checks and adjustments to ensure the operational readiness of the equipment and to prevent, insofar as possible, unexpected malfunction or failure of the equipment, and (2) troubleshooting tasks, which are generally initiated as a result of a malfunction indication on an equipment console or as a result of a failed procedural maintenance checkout step not correctable by an immediately identifiable adjustment.

Participants

Two groups of personnel will be used as test participants. One group will consist of 16 NSSMS "C" school students who have completed that part of the curriculum that covers the experimental tasks. This group will be considered trained, but inexperienced. The second group will consist of 16 NSSMS "C" school graduates who have been in the fleet working on NSSMS for at least one year. This group will be considered trained and experienced.

Experimental Design

The independent variables of interest are: technical information delivery system (PEAM and paper), technician experience (inexperienced and experienced), and type of maintenance (procedural and troubleshooting).

Participants will serve as their own controls. Each technician will perform two comparable procedural maintenance tasks and two troubleshooting tasks using PEAM for one of each and conventional paper-based documentation for the others. To avoid possible experimental bias due to order effects, the sequences of task combinations will be counterbalanced.

The overall experimental design that will be used to collect the data will have the following structure:

Table A-1

Structure of Experimental Design

	Electronic Documentation (n = 64)		Paper-based Documentation (n = 64)	
Troubleshooting n = 64	Experienced technician (n = 16)	Inexperienced technician (n = 16)	Experienced technician (n = 16)	Inexperienced technician (n = 16)
Procedural n = 64	Experienced technician (n = 16)	Inexperienced technician (n = 16)	Experienced technician (n = 16)	Inexperienced technician (n = 16)

Notes.

1. n = number of data points contributing to each cell mean.

2. Since each technician will provide data for four cells in the design matrix, the data could well be correlated: that fact will be taken into account in the ANOVA calculations.

3. There are several sources of contamination both within and between the troubleshooting and procedural maintenance task comparisons. For example, for procedural maintenance, the transit between work center and job site may be materially different aboard ship and at the NSSMS school or even aboard different NSSMS ships. Also, the number and kinds of required actions may differ (and thus the time required and potential for error may differ) between procedural maintenance and troubleshooting tasks. These, too, will be accounted for before making the comparative analyses.

Measures

Two types of measures will be collected for both procedural maintenance and troubleshooting tasks, namely time measures and frequency counts. The following three lists outline the steps in the task sequence to be timed and the frequency counts to be taken.

Table A-2

Time Measures: Procedural Maintenance

Time Interval	Task Sequence
	Initiation
Start	Task assigned to technician
	Preparation
1.	Obtain MRC or PEAM unit and information module; activate PEAM
2.	Verify MRC/information module against Maintenance Index Page (MIP)
3.	Review safety precautions
4.	Assemble/prepare tools, equipment, materials for transport to job site
5.	Transit to job site
6.	Set up equipment, etc., at job site
	Conduct Procedural Maintenance Task
7.	Perform sequential task steps as presented on MRC/PEAM; encounter maladjustment; identify adjustment task
	Prepare for Adjustment Task
8.	Return to work center; obtain MRC/information module and verify currency against MIP; assemble tools, equipment, materials; return to job site (NOTE: If primary PEAM module contains adjustment task information and no additional equipment, etc., is required, technician using PEAM does not need to return to work center.)
	Adjustment Task
9.	Perform adjustment task
	Continue Procedural Maintenance Task
10.	Complete remaining sequential procedural maintenance task steps
	Termination
11.	Pack up equipment, tools, materials, PEAM
12.	Transit to work center
13.	Stow MRC/PEAM and module, gear
14.	Complete maintenance log/report as required

Table A-3

Time Measures: Troubleshooting

Time Interval	Task Sequence
	Initiation
Start	Activate portable computer (PC); read problem symptoms; obtain TM/activate PEAM
	Conduct Troubleshooting Task
1	Search TM/PEAM for desired information; obtain information; decide test to make; perform test (designate to PC); read result on PC
2a, b...n	Repeat 1 until fault tentatively located
3	Identify part number and "replace" (enter number into PC)
	Termination
4	Report maintenance action taken; initiate part restocking (enter into PC)

Table A-4

Frequency Counts

Procedural Maintenance Tasks	Troubleshooting
(a) Steps performed	(a) Steps performed
(b) Steps performed incorrectly[1]	(b) Steps performed incorrectly[3]
(c) Required steps not performed	(c) Inappropriate test performed[4]
(d) Non-required steps performed	(d) False removals
(e) Steps performed out of sequence[2]	(e) Number of references to documentation
(f) Number of references to documentation (The number of steps required by the documentation will also be noted.)	(f) Number of reference errors[5]
(g) Number of uses of voice input (PEAM)	(g) Number of uses of voice input (PEAM)
(h) Number of uses of speech output (PEAM)	(h) Number of uses of speech output (PEAM)

[1] Other than as specified in documentation.

[2] Other than in order specified in documentation; if the specified order is next resumed, only one count will be recorded, otherwise additional counts will accumulate until correct sequence is resumed; if the validity of a step is contingent on a skipped step, it will be counted as both incorrect and out of sequence.

[3] Incorrect steps include faulty readings (e.g., volts versus ohms), readings at wrong test point, acceptance of an out-of-tolerance reading or rejection of an in-tolerance reading, etc.

[4] A test is inappropriate if it provides no useful diagnostic information at the time it is made.

[5] Includes reference to inappropriate listing, directory, chart, etc.; incorrect identification of line item, test point number/location; incorrect test value, part number, etc.

As presented above, technician performance will be measured in several ways. Analyses will be performed as necessary to test the various hypotheses on the several dimensions.[1] The design of the experiment will permit the use of a 2 x 2 x 2 analysis of variance (ANOVA) for many of these tests. Some tests, however, are not amenable to the 2 x 2 x 2 ANOVA approach. For example, a 2 x 2 x 2 ANOVA cannot be used for comparisons of the number of steps taken. There is no a priori minimum, maximum, or optimum number of steps for the troubleshooting tasks. There are a specified number of required steps for the procedural maintenance tasks, however. The number of steps actually taken in the troubleshooting tasks may be the same, fewer, or more than those in the procedural maintenance tasks. There is no common basis for comparing them, they come essentially from two separate statistical universes, and the 2 x 2 x 2 ANOVA is inappropriate. The design of the experiment does, however, permit hypothesis testing using a 2 x 2 ANOVA, and this will be performed. Where the ANOVA designs are inappropriate, for example, the frequency of use for the PEAM voice input, correlational analyses will be used.

User Questionnaires

The performance quantitative measures provide adequate data to evaluate the hypotheses concerning the effects of the information delivery systems on technicians' performance. However, these measures do not address the strengths and weaknesses of design features of the delivery systems nor the acceptance issues associated with the introduction of a new device. To gain this complementary information, a user questionnaire will be administered to the participants following their use of both the paper-based system and PEAM. The answers obtained will help evaluate the physical layout of the displays and controls, the quality of the visual and aural displays, the format and completeness of the information, and the potential acceptance of the delivery devices. Information provided by this questionnaire along with the quantitative performance data will also provide a sound basis upon which to compare PEAM with MRCs and OPs.

PART II: ASSESSMENT OF FLEET IMPLEMENTATION ISSUES

Typically, there are many problems associated with the introduction of new equipment into the fleet and some of these problems have the potential of critically affecting the acceptance of an innovation by members of the intended user group. Problems have to be identified and the actions that should be taken to alleviate or overcome them described.

The implementation issues addressed are: (1) user considerations, (2) logistical support considerations, (3) training considerations, and (4) interface considerations. While it is recognized that these issues focus on the NSSMS, it is anticipated that many of the findings obtained during this phase will be generalizable to other Navy systems and equipments that could be supported by an electronically-based maintenance information delivery system such as PEAM.

Objective

The objective of Part II is to use structured interviews and observation forms and pertinent Navy and/or contractor-prepared documentation to obtain the information needed to address fleet implementation issues.

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[1] See "Experimental Hypotheses and Design" in the body of this report.

User Considerations

The acceptance of PEAM by NSSMS maintenance technicians can be facilitated by assessing factors of concern to these personnel. Accordingly, this section discusses the types of questions and problems that need to be addressed with respect to the users.

1. How many PEAM devices will be needed to support shipboard maintenance of the NSSMS? Assessments will be conducted to determine the number of PEAM devices needed to support maintenance of the NSSMS in an efficient manner.

2. Where should the PEAM device(s) and associated software be located aboard ship? Assessments will be conducted to determine the optimal storage location(s) for PEAM and its associated memory modules. Procedures would have to be developed to ensure that the PEAM device and memory modules were returned to their proper location when not in service and to ensure that required preventive maintenance actions were performed on the devices. For these reasons, careful consideration must be given to the tradeoffs between centralized versus decentralized storage of the PEAM devices and modules aboard ship.

3. What is required to prepare PEAM for maintenance activities? In the context of the Navy's planned maintenance system, a schedule of preventive maintenance is established and reviewed daily to determine what tasks have to be performed. Accordingly, information will be obtained regarding how such a system should be structured, including such possible approaches as: (1) organizing modules according to major system functions (e.g., both preventive/corrective maintenance information for major components of the NSSMS stored on the same memory module), (2) placing labels on the outside of the modules that provide a general overview of their contents, and/or (3) developing a master index of all NSSMS technical information available from PEAM on a separate memory module.

4. What problems are anticipated in transporting PEAM to the work site? It will be necessary to determine how easily PEAM can be transported from its storage location to various work sites. The weight and bulk of the device represent one of the more serious factors relating to potential resistance to change by users (especially when compared with existing sources of procedural information such as the maintenance requirement card).

5. What problems are anticipated in setting up PEAM for use at the work site? Clearly, the loading of the module at the storage location, transporting the device to the work site, and setting up PEAM for operation require more expenditure of effort than would be required for the current paper-based technical information delivery system. This state of affairs raises the question as to whether or not the benefits of using PEAM outweigh the extra effort involved in its use.

6. What problems are anticipated in the day-to-day use of PEAM? Here, consideration must be given to the following factors:

a. Potential safety problems that may result from connecting cables between the device, ship's power, and/or the DC battery pack; as well as connections between the headset and the device (e.g., on or near rotating machinery, or near high voltage power supplies).

b. The vulnerability of PEAM to breakage/damage from being dropped.

c. The practicality of the audio input/output features in a high-noise environment (e.g., the flight deck during flight operations, in or near machinery spaces).

d. Interference produced by wearing the headset for the PEAM device at the same time sound-powered headphones/ear protective gear are worn by the technician.

Logistical Support Considerations

The following represent the types of questions and problem areas that will need to be addressed regarding logistical support for the PEAM device and its associated software.

1. How will updating/correction of the PEAM software be accomplished? Because the PEAM software will consist of exchangeable, plug-in memory modules, it is necessary to determine how often, and when, corrections, revisions, and updates will be needed. Considering that PEAM represents an entirely new concept for delivering technical information, methods must be developed for periodically updating and revising the PEAM software to reflect the addition of new equipments or maintenance procedures, modifications to existing equipment or procedures, or to delete these portions of the data base that are obsolete or have been superseded.

2. What are the storage/safeguard requirements for the PEAM device and associated modules? An assessment of the physical storage requirements for the PEAM device and memory modules will be conducted. This assessment will entail comparing the storage requirements for the estimated number of PEAM devices and memory modules with those for current NSSMS maintenance documentation.

3. What sort of shipboard backup capability is needed to support PEAM? Because it is very likely that the PEAM memory modules could be damaged or lost in day-to-day usage, consideration must be given to providing some sort of shipboard backup system.

4. Who will be responsible for the maintenance of and spare parts supply for PEAM? An issue of critical importance will be to determine who will have responsibility for repairing PEAM at the organizational (i.e., ship's force) level and, similarly, who will have responsibility for ensuring that repair parts and replacement components are readily available.

5. Should a "print-on-demand" capability be provided for PEAM? Assessments will be conducted to determine both the need for as well as the feasibility and practicality of providing a "print-on-demand" capability for information contained in the PEAM data base.

Training Considerations

This section discusses questions and problem areas regarding operator training for PEAM as well as other types of training that could be supported by it.

1. How will NSSMS technicians learn to operate PEAM? PEAM appears to be an ideal candidate for the inclusion of an embedded training capability wherein technicians could learn the basic operation and use of the device on line.

2. What other types of training could be supported by PEAM? Another aspect of this embedded training capability deals with the potential PEAM may have to complement shipboard training programs that are currently being conducted in the areas of preventive and corrective maintenance.

Interface Considerations

The following represent the types of questions and problem areas that will need to be addressed with respect to interfacing PEAM with existing or developing maintenance/logistical support systems.

1. Can PEAM be interfaced with state-of-the-art diagnostic capabilities? The feasibility of interfacing PEAM with "smart" built-in test (BIT) equipment or devices that provide an automated fault detection/isolation capability will be assessed in the course of this evaluation. Conceivably, PEAM could be designed to be patched into the above types of equipments and devices to provide it with an on-line diagnostic capability, or alternatively, the diagnostic algorithms for these equipments and devices could be downloaded onto PEAM memory modules.

2. Can PEAM be interfaced with state-of-the-art word processing capabilities? Assessments will be conducted to determine both the need for, and feasibility of, interfacing a unit with PEAM that would automate the preparation and processing of standard Navy maintenance reports and forms (e.g., OPNAV 4790.2-series reports, supply requisition forms, and reports documenting accomplishment of scheduled maintenance activities).

APPENDIX B

EXAMPLES OF TROUBLESHOOTING INFORMATION FRAMES FROM AUTOMATED NSSMS DATA BASE

INTRODUCTION

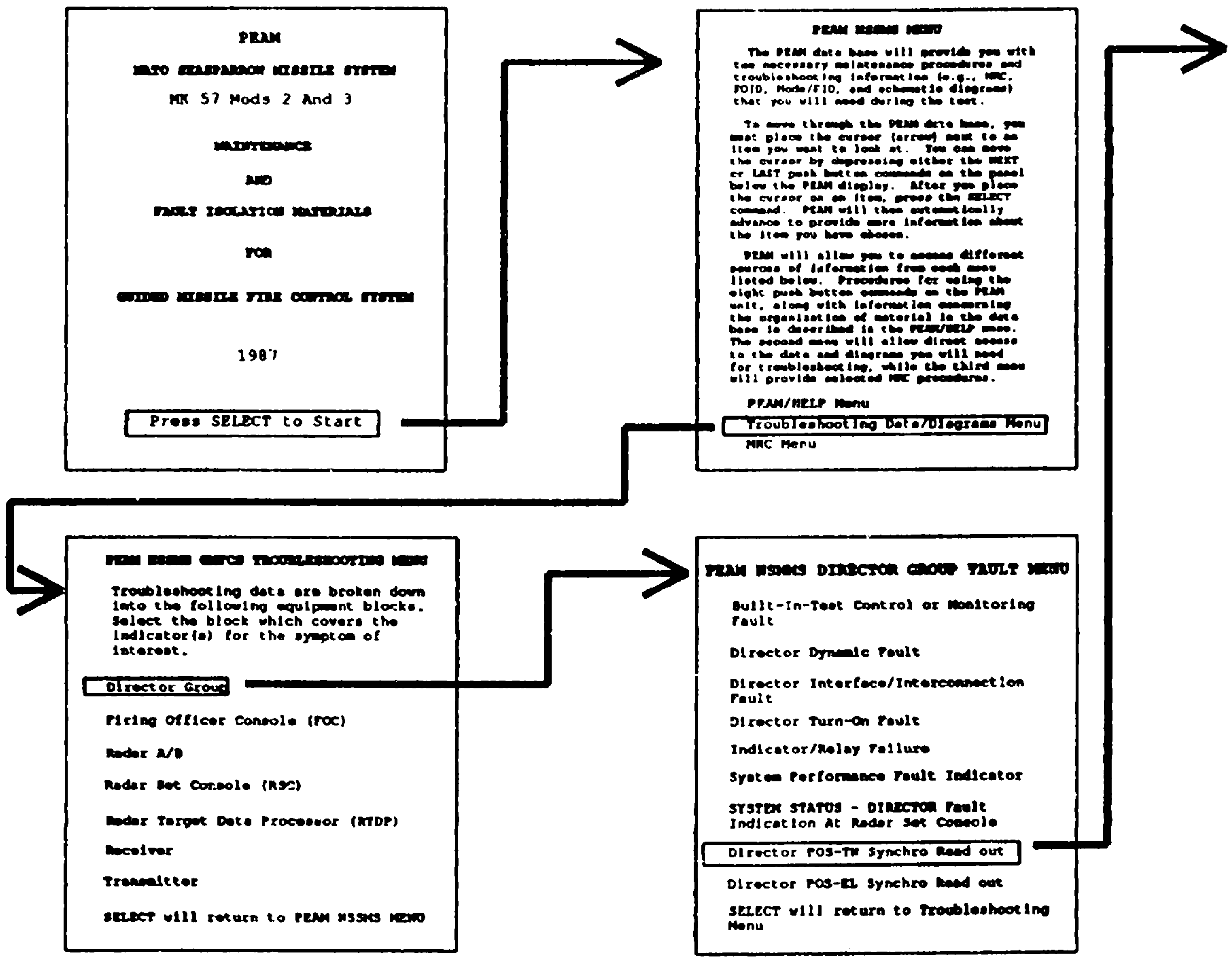
This appendix represents examples of selected troubleshooting information frames used in conjunction with the director control unit printed circuit card failure.[1] The specific malfunction involved is the "open" pin (XA18-4) on the 7/8A1A18 bite off-line oscillator circuit.

The NSSMS data base was structured to provide information for: (1) initiating troubleshooting actions, (2) isolating the failure to the affected printed circuit card and component, (3) identifying stock numbers for replacement parts, and (4) describing the physical and functional characteristics of major circuits within the NSSMS. Accordingly, the following sections provide both verbal and graphic descriptions of the sequence of actions needed to access the above types of information.

Initiating Troubleshooting

To accomplish this process, technicians were required to select an item from each of the frames shown on the opposing page. The title frame for the NSSMS data base, which served as the "starting point" for each technician, is shown in the upper left panel. By the technician placing the cursor on the "Press SELECT to Start" item, the computer automatically advanced to the PEAM NSSMS MENU frame shown in the upper right panel. By the technician selecting the "Troubleshooting Data/Diagrams Menu" item from this frame, the computer advanced to a frame listing major units of the NSSMS for which corrective maintenance information was available (lower left panel). The selection of the "Director Group" item from this frame led to a menu of faults for the NSSMS director group (lower right panel). At this point, technicians were required to select an item from the director group fault menu that most closely corresponded to the major casualty symptom(s) presented on the IBM PC. By the technician selecting the "Director POS-TN Synchro Read out" item, the computer advanced to the Fault-Oriented Interconnection Diagram (FOID) frame for the 7/8A1A3 printed circuit card depicted in the upper left panel on page B-4.

[1]The frames in this appendix represent approximately 2 percent of the 984 troubleshooting frames that comprise the NSSMS data base; thus, they are intended to be representative, but not exhaustive. In addition, each example frame has been photo-reduced by two-thirds of its original 5 x 7 inch (12.7 x 17.8 cm) display size on the Sun model 3/75 computer.


PEAM
NATO SEASPARROW MISSILE SYSTEM
MK 57 Mods 2 And 3
MAINTENANCE
AND
FAULT ISOLATION MATERIALS
FOR
GUIDED MISSILE FIRE CONTROL SYSTEM
1987
Press SELECT to Start
PEAM NSSMS MENU
The PEAM data base will provide you with the necessary maintenance procedures and troubleshooting information (e.g., MRC, FOID, Mode/FID, and schematic diagrams) that you will need during the test.
To move through the PEAM data base, you must place the cursor (arrow) next to an item you want to look at. You can move the cursor by depressing either the NEXT or LAST push button commands on the panel below the PEAM display. After you place the cursor on an item, press the SELECT command. PEAM will then automatically advance to provide more information about the item you have chosen.
PEAM will allow you to access different sources of information from each menu listed below. Procedures for using the eight push button commands on the PEAM unit, along with information concerning the organization of material in the data base is described in the PEAM/HELP menu. The second menu will allow direct access to the data and diagrams you will need for troubleshooting, while the third menu will provide selected MRC procedures.
PEAM/HELP Menu
Troubleshooting Data/Diagrams Menu
MRC Menu
PEAM NSSMS GMFCS TROUBLESHOOTING MENU
Troubleshooting data are broken down into the following equipment blocks. Select the block which covers the indicator(s) for the symptom of interest.
Director Group
Firing Officer Console (FOC)
Radar A/B
Radar Set Console (RSC)
Radar Target Data Processor (RTDP)
Receiver
Transmitter
SELECT will return to PEAM NSSMS MENU
PEAM NSSMS DIRECTOR GROUP FAULT MENU
Built-In-Test Control or Monitoring Fault
Director Dynamic Fault
Director Interface/Interconnection Fault
Director Turn-On Fault
Indicator/Relay Failure
System Performance Fault Indicator
SYSTEM STATUS - DIRECTOR Fault Indication At Radar Set Console
Director POS-TN Synchro Read out
Director POS-EL Synchro Read out
SELECT will return to Troubleshooting Menu

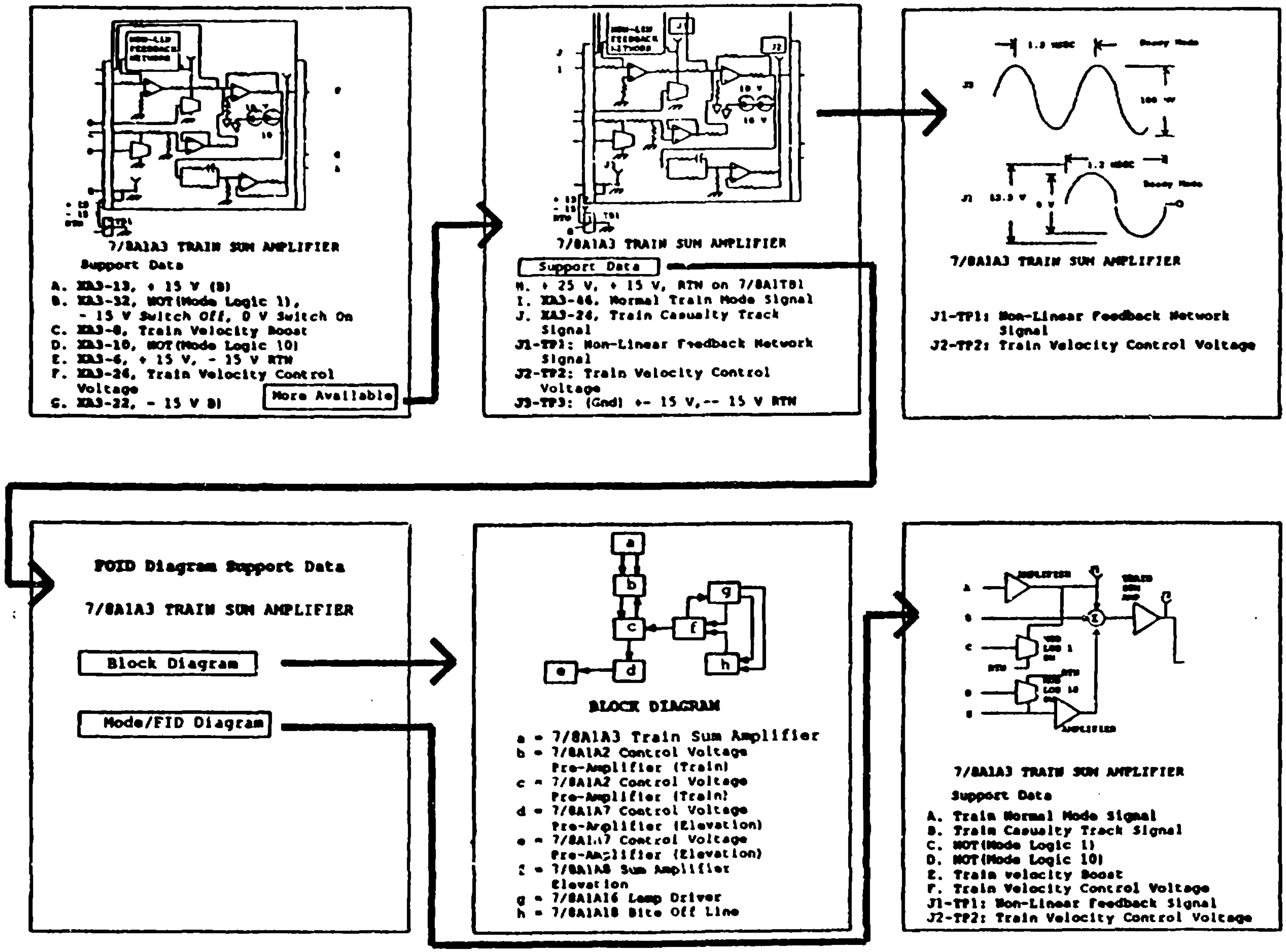
Isolating the Failure--General

The six frames depicted on the opposing page are examples of the types of fault isolation data and diagrams continued in the NSSMS data base. The two frames shown in the upper left and upper center panels are FOIDs for the train sum amplifier circuit. Several features of these frames need to be pointed out. Due to the limited size of the PEAM display, signal names and their associated parameters (e.g., proper operating voltage, logic, resistance levels) could not be combined with schematic illustration of the circuit--as is the case with conventional maintenance publications. For that reason, the FOIDs contained in the NSSMS data base were divided into a "graphic" and a "text" portion, occupying the upper and lower halves of the frame, respectively. Cross-referencing between these portions was accomplished by the alphabetic or alphanumeric characters shown in the examples.

It should also be noted that the amount of text required to fully identify signal lines, test points, etc., and their associated parameters for particular circuit cards could not always be accommodated in a single frame. In those cases, FOIDs were divided into two or more "continuation" frames in which the graphic portion of the printed circuit card remained the same, but the labels and text used to identify signal lines, test points, etc., changed. Notice also that a "More Available" item appears at the bottom of the frame in the upper left panel. By the technician selecting that item, the computer advanced to the continuation frame for the 7/8A1A3 printed circuit card.

Inspection of the graphic portion of the FOID frame in the upper center panel shows test points J1 and J2 enclosed in boxes. By the technician selecting either of these items from the graphic, the computer advanced to the next frame, appearing here in the upper right panel (i.e., showing waveforms that should be present at each test point). All FOID frames in the data base also contained a "Support Data" item. By the technician selecting this item, the computer advanced to the next frame, shown here in lower left panel. The block diagram (lower center panel) provided the user with a general overview of the configuration of printed circuit cards within the NSSMS director control group. Moreover, the user could obtain direct access to any of the director group FOID frames by simply selecting a lower-case letter from the graphic portion of the block diagram. This feature offered considerable flexibility in specifying the number and order of printed circuit cards to be tested during the fault isolation process.

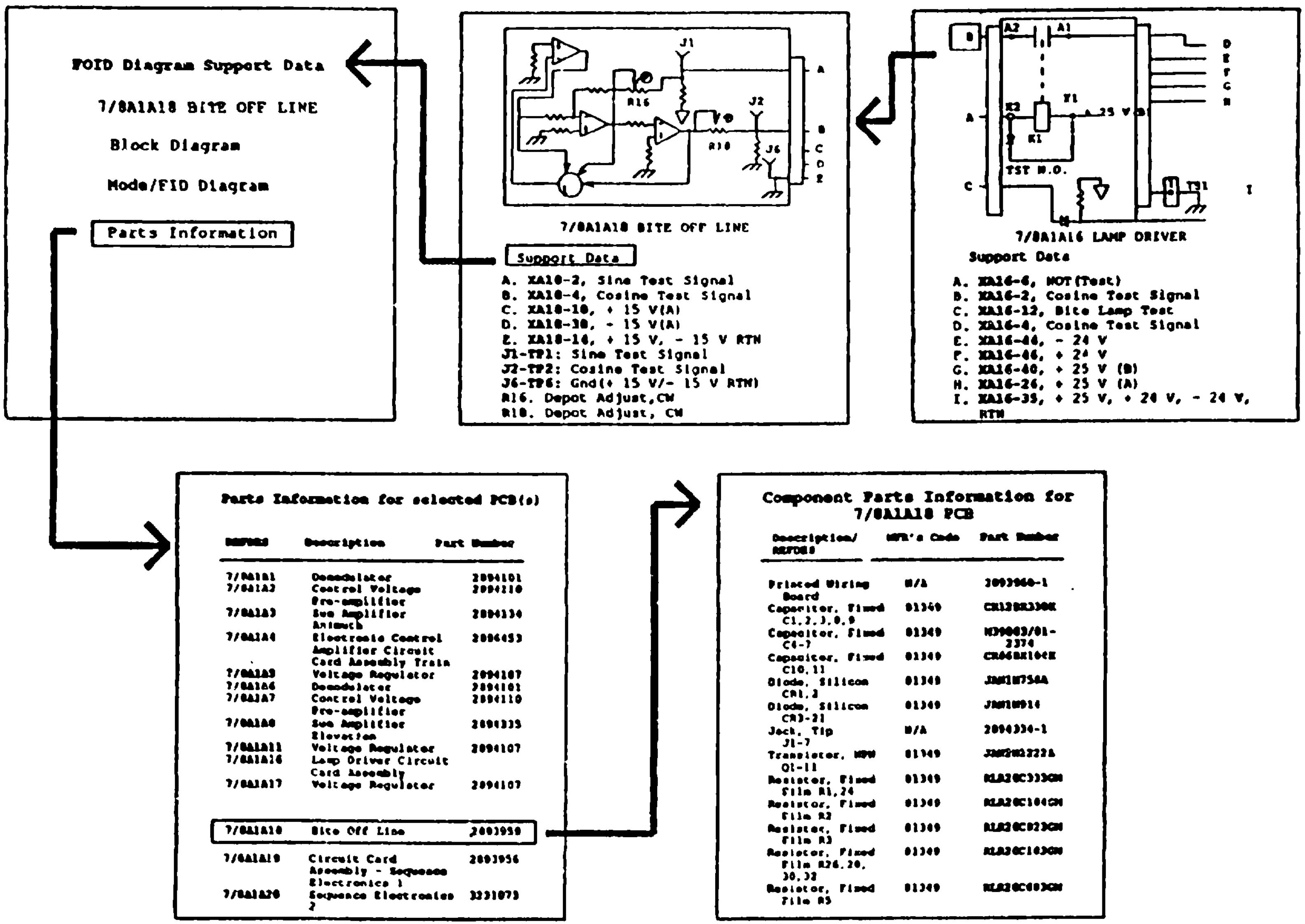
The second item on the support data menu provided direct access to simplified signal flow information for the NSSMS director group--collectively referred to as Mode/Fault Isolation and Detection (FID) diagrams. The principal distinction between the FOID and Mode/FID diagrams is that the latter excludes references to discrete card pins and circuit operating parameters (e.g., compare signal line "B" from the FOID in the upper left panel with signal line "C" from the Mode/FID diagram in the lower right panel).


7/8A1A3 TRAIN SUM AMPLIFIER
Support Data
A. XA3-13, + 15 V (B)
B. XA3-32, NOT(Mode Logic 1), - 15 V Switch Off, 0 V Switch On
C. XA3-8, Train Velocity Boost
D. XA3-10, NOT(Mode Logic 10)
E. XA3-6, + 15 V, - 15 V RTN
F. XA3-26, Train Velocity Control Voltage
G. XA3-22, - 15 V B)
More Available
7/8A1A3 TRAIN SUM AMPLIFIER
Support Data
H. + 25 V, + 15 V, RTN on 7/8A1TB1
I. XA3-46, Normal Train Mode Signal
J. XA3-24, Train Casualty Track Signal
J1-TP1: Non-Linear Feedback Network Signal
J2-TP2: Train Velocity Control Voltage
J3-TP3: (Gnd) +- 15 V,-- 15 V RTN
Ready Mode
7/8A1A3 TRAIN SUM AMPLIFIER
J1-TP1: Non-Linear Feedback Network Signal
J2-TP2: Train Velocity Control Voltage
FOID Diagram Support Data
7/8A1A3 TRAIN SUM AMPLIFIER
Block Diagram
Mode/FID Diagram
BLOCK DIAGRAM
a = 7/8A1A3 Train Sum Amplifier
b = 7/8A1A2 Control Voltage Pre-Amplifier (Train)
c = 7/8A1A2 Control Voltage Pre-Amplifier (Train)
d = 7/8A1A7 Control Voltage Pre-Amplifier (Elevation)
e = 7/8A1A7 Control Voltage Pre-Amplifier (Elevation)
f = 7/8A1A8 Sum Amplifier Elevation
g = 7/8A1A16 Lamp Driver
h = 7/8A1A18 Bite Off Line
7/8A1A3 TRAIN SUM AMPLIFIER
Support Data
A. Train Normal Mode Signal
B. Train Casualty Track Signal
C. NOT(Mode Logic 1)
D. NOT(Mode Logic 10)
E. Train velocity Boost
F. Train Velocity Control Voltage
J1-TP1: Non-Linear Feedback Signal
J2-TP2: Train Velocity Control Voltage

Isolating the Failure--Specific

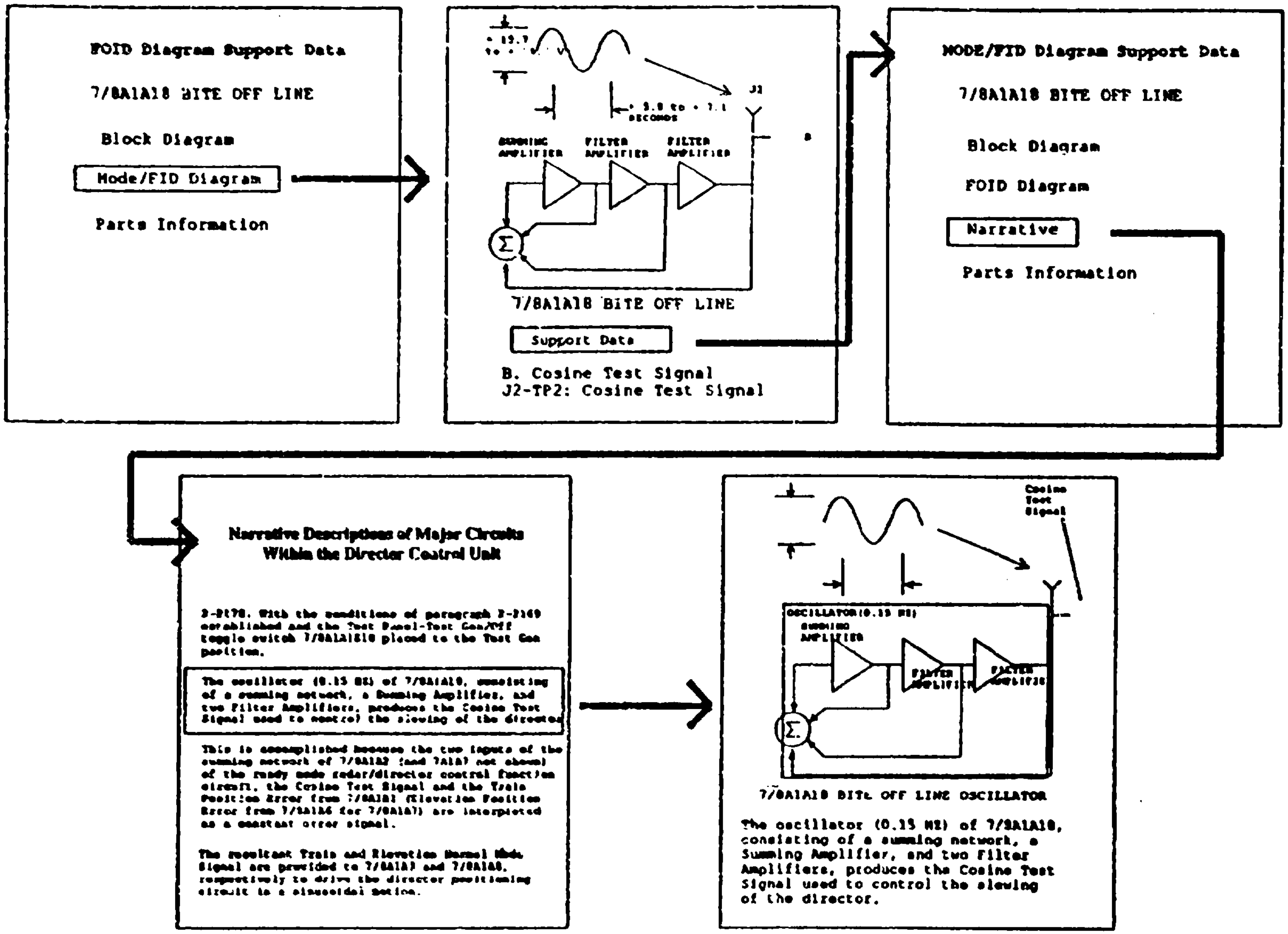
The five frames depicted on the opposing page show the sequence of actions needed to isolate the failure to the affected printed circuit card and component as well as for locating replacement parts information. The sequence began in the upper right hand panel (i.e., FOID for the 7/8A1A16 lamp driver circuit). After finding no output at pin 2 (i.e., signal line "B") of the 7/8A1A16 card, the technician selected item "B" on the graphic portion of the FOID. The computer then advanced to the frame in the upper center panel, which is the FOID for the bite off-line circuit. The technician then performd a voltage, frequency, or waveform test at "J2-TP2" to determine if the bite off-line oscillator was producing a proper cosine test signal. After verifying the proper signal reading at J2-TP2, the technician obtained an incorrect reading at pin 4 (i.e., signal line "B") of the 7/8A1A18 card--thereby isolating the failure to that card and component. (The tests performed at J2-TP2 and pin 4 on the 7/8A1A18 card were considered to be "proof points" for conclusively isolating the failure.)

Once the failure had been isolated, the technician was asked to locate parts information for the 7/8A1A18 printed circuit card. This was accomplished by selecting the "Support Data" item from the FOID frame (upper center panel), which, in turn, branched to the FOID Diagram Support Data frame, displayed here in the upper left panel. By the technician selecting the "Parts Information" item from that frame, the computer advanced to the frame shown in the lower left panel. Once the part number for a replacement 7/8A1A18 had been located, the technician was asked to locate the part number for a "blank" wiring board for that printed circuit card. (This action presumed that discrete components from the malfunctioning card could be transferred to a known good wiring board.) To obtain this information, the technician selected the "bite off-line" item from the frame (lower left panel), which then branched to the frame shown in the lower right panel. Note that the "blank" printed wiring board is the first item listed on that frame.


FOID Diagram Support Data
7/8A1A18 BITE OFF LINE
Block Diagram
Mode/FID Diagram
Parts Information
7/8A1A18 BITE OFF LINE
Support Data
A. XA18-2, Sine Test Signal
B. XA18-4, Cosine Test Signal
C. XA18-10, + 15 V(A)
D. XA18-30, - 15 V(A)
E. XA18-14, + 15 V, - 15 V RTN
J1-TP1: Sine Test Signal
J2-TP2: Cosine Test Signal
J6-TP6: Gnd(+ 15 V/- 15 V RTN)
R16. Depot Adjust,CW
R18. Depot Adjust, CW
7/8A1A16 LAMP DRIVER
Support Data
A. XA16-6, NOT(Test)
B. XA16-2, Cosine Test Signal
C. XA16-12, Bite Lamp Test
D. XA16-4, Cosine Test Signal
E. XA16-44, - 24 V
F. XA16-46, + 24 V
G. XA16-40, + 25 V (B)
H. XA16-26, + 25 V (A)
I. XA16-35, + 25 V, + 24 V, - 24 V, RTN
Parts Information for selected PCB(s)
REFDES Description Part Number
7/8A1A1 Demodulator 2894101
7/8A1A2 Control Voltage Pre-amplifier 2894110
7/8A1A3 Sum Amplifier Azimuth 2894334
7/8A1A4 Electronic Control Amplifier Circuit Card Assembly Train 2894453
7/8A1A5 Voltage Regulator 2894107
7/8A1A6 Demodulator 2894101
7/8A1A7 Control Voltage Pre-amplifier 2894110
7/8A1A8 Sum Amplifier Elevation 2894335
7/8A1A11 Voltage Regulator 2894107
7/8A1A16 Lamp Driver Circuit Card Assembly
7/8A1A17 Voltage Regulator 2894107
7/8A1A18 Bite Off Line 2893958
7/8A1A19 Circuit Card Assembly - Sequence Electronics 1 2893956
7/8A1A20 Sequence Electronics 2 3231073
Component Parts Information for 7/8A1A18 PCB
Description/ REFDES MFR's Code Part Number
Printed Wiring Board N/A 2893960-1
Capacitor, Fixed C1,2,3,8,9 81349 CK13BX330K
Capacitor, Fixed C4-7 81349 M39003/01-2374
Capacitor, Fixed C10,11 81349 CK06BX104K
Diode, Silicon CR1,2 81349 JAN1N754A
Diode, Silicon CR3-21 81349 JAN1N914
Jack, Tip J1-7 N/A 2894334-1
Transistor, NPN Q1-11 81349 JAN2N2222A
Resistor, Fixed Film R1,24 81349 RLR20C333GN
Resistor, Fixed Film R2 81349 RLR20C104GN
Resistor, Fixed Film R3 81349 RLR20C823GN
Resistor, Fixed Film R26,28,30,32 81349 RLR20C103GN
Resistor, Fixed Film R5 81349 RLR20C683GN

Locating Narrative Information

The five frames shown on the opposing page show the sequence of actions that were performed to locate narrative descriptions of the physical and functional characteristics of the 7/8A1A18 printed circuit card. This sequence began by the technician selecting the "Mode/FID Diagram" item from the frame in the upper left panel. This item branched to the Mode/FID diagram for the bite off-line circuit shown in the upper center panel. Note that this frame contains a "Support Data" item, which, when selected, branches to the frame in the upper right panel. By the technician selecting the "Narrative" item from that frame, the computer advanced to the frame shown in the lower left panel. By placing the cursor on any of the four "text blocks" on that frame, the user obtained an integrated test and graphic display of the narrative description--as shown in the lower right panel.


FOID Diagram Support Data
7/8A1A18 BITE OFF LINE
Block Diagram
Mode/FID Diagram
Parts Information
SUMMING AMPLIFIER
FILTER AMPLIFIER
FILTER AMPLIFIER
J2
7/8A1A18 BITE OFF LINE
Support Data
B. Cosine Test Signal
J2-TP2: Cosine Test Signal
MODE/FID Diagram Support Data
7/8A1A18 BITE OFF LINE
Block Diagram
FOID Diagram
Narrative
Parts Information
Narrative Descriptions of Major Circuits
Within the Director Control Unit
Cosine Test Signal
OSCILLATOR (0.15 HZ)
SUMMING AMPLIFIER
7/8A1A18 BITE OFF LINE OSCILLATOR
The oscillator (0.15 HZ) of 7/8A1A18, consisting of a summing network, a Summing Amplifier, and two Filter Amplifiers, produces the Cosine Test Signal used to control the slewing of the director.

APPENDIX C

USER EVALUATION QUESTIONNAIRE FORM

USER EVALUATION QUESTIONNAIRE

Introduction

Because **PEAM** is still undergoing development, it is important to obtain an evaluation of the current model from Navy technicians who have had some "hands on" experience with it. This questionnaire is designed for that purpose. You are asked to evaluate the strengths and weaknesses of **PEAM** in terms of its (1) physical features, (2) information presentation, and (3) overall contribution to task performance as compared to current maintenance documents for the **NSSMS**.

Specifically, we ask you to evaluate the questionnaire items using the 5-point scale appearing to the right of the items. Rate each item by placing an "X" in the appropriate column. We encourage you to respond to as many of the questionnaire items as possible but recognize that there may be some items you <u>cannot</u> evaluate based on your limited experience with the **PEAM** device. In those cases, place an "X" in the column headed: "Can't Evaluate".

Section 1: Physical Features

Items 1 through 10 concern the display screen.

	Scale Values					
Items	Unsatis-factory	Marginal	Satisfactory	Highly Satisfactory	Outstanding	Can't Evaluate
1. Ease of operating mouse control						
2. Indication(s) that mouse command had been activated						
3. Adequacy of frame size for displaying information						
4. Spacing of information on the display screen (i.e., lack of clutter/crowding)						
5. Brightness of the display						
6. Contrast between information on the display and background						
7. Legibility of displayed letters and words						
8. Format/arrangement of graphic displays (e.g., schematics, block diagrams, IPBs)						
9. Resolution and clarity of graphic displays						
10. Adequacy of detail on graphic displays						

Section 2: Operation and Software Features

Items 11 through 17 concern the following operation and software features:

- Organization and arrangement of maintenance information
- Ease of obtaining relevant maintenance information
- Extent to which computer is "user-friendly"

Items	Scale Values: Unsatis-factory	Marginal	Satisfactory	Highly Satisfactory	Outstanding	Can't Evaluate
11. Adequacy of the organization and arrangement of maintenance information						
12. Adequacy of options available on menus						
13. Ease of using menus to obtain different types of maintenance information (e.g., MODE/FID diagrams, parts information)						
14. Ease of obtaining specific information within a particular type of maintenance information (e.g., locating a specific part in the parts info.)						
15. Adequacy of troubleshooting diagrams						
16. Adequacy of information for supporting maintenance tasks (i.e., completeness, accuracy, relevancy)						
17. Adequacy of "prompts" on the displays for assisting/guiding the operator						

Section 3: Comparative Assessment (Computer versus Paper Documentation)

This section of the questionnaire deals with the efficiency and effectiveness of the computer as compared to current maintenance documents for the **NSSMS**, such as MRCs, UMRCs, and OPs. Note that the words listed under the heading scale values have changed. Please review this scale carefully before rating the items.

To avoid repetition in the wording of the items contained in this section, begin each with the phrase:

Compared to current maintenance documents for the NSSMS, how would you rate the computer in terms of ...

	Scale Values					
Items	Significantly Less	Slightly Less	No Difference	Slightly More	Significantly More	Can't Evaluate
18. The overall time and effort required to obtain maintenance information						
19. The fatigue you experience when using it						
20. The confusion or frustration you experience in obtaining needed maintenance information						
21. The extent to which it represents improvement in the overall organization and arrangement of maintenance information						
22. The extent to which it represents improvement in obtaining needed maintenance information						
23. The extent to which it represents improvement in the presentation of maintenance information						
24. The extent to which it represents improvement in the overall completeness, accuracy, and applicability of maintenance information						
25. The extent to which it represents improvement in supporting maintenance on the **NSSMS**						

Section 4: General Reactions and Comments

The spaces below are provided for making any comments, complaints, suggestions, etc., you have regarding the current model of the **PEAM** device.

This concludes the user evaluation questionnaire. Your assistance in providing this essential information is appreciated.

APPENDIX D

STRUCTURED INTERVIEW QUESTIONS AND RESPONSES

Section 1

Interview Questions Regarding User Considerations[1]

The first two questions deal with the number of PEAM devices needed to support maintenance of the SEASPARROW in an efficient manner.

1. If PEAM were the only source of technical information, how many PEAM devices do you think would be needed to maintain a single SEASPARROW system?

	Number of Devices					
	One	Two	Three	Four	Five	Totals
CV	0	6	2	2	1	11
DD 963	1	4	6	1	2	14
Totals	1	10	8	3	3	25

2. Can you give some of the reasons why you think this number would be adequate to support the maintenance requirements for a single SEASPARROW system?

	CV	DD 963	Totals
a. Convenience of multiple locations	3	9	12
b. Backup capability	3	4	7
c. Can have multiple jobs going on at same time	5	0	5
Totals	11	13	24

[1]The totals reported for individual questions do not always sum to 25 (i.e., the number of technicians included in the sample). In some cases, technicians simply did not respond to questions, while in others, they provided multiple responses--each of which was counted separately.

The next two questions concern the physical placement of PEAM on board ship.

3. If it is determined that one PEAM device is needed per SEASPARROW system, where do you think it should be located and why?

		CV	DD 963	Totals	Why?
a.	Computer room	0	13	13	Central location.
b.	Control room/work center	8	0	8	Central location.
c.	Transmitter room	2	0	2	Most vital equipment; frequent problems.
d.	Radar control room	1	0	1	
	Totals	11	13	24	

4. If it is determined that two or more PEAM devices are needed per SEASPARROW system, the devices could be located in a central location or at different locations on board ship. Which type of arrangement do you think would be best and why?

	CV	DD 963	Totals	Why?
Centralized	3	5	8	Accountability, convenience, keep together with tools, other aids.
Decentralized	8	9	17	More convenient, better survival in case of attack.
Totals	11	14	25	

The next five questions are based on the assumption that the overall PEAM data base for the SEASPARROW system will consist of several memory modules—perhaps as many as 10 or more. To a certain extent, this requirement would be similar to the library of program tapes needed to support SEAT equipment. Accordingly, we are interested in determining where these modules might be located and how they might be organized so that SEASPARROW technicians could locate needed maintenance information quickly and efficiently.

5. If only one set of PEAM modules were provided for the SEASPARROW system, where do you think it should be located and why?

	CV	DD 963	Totals
Same location as PEAM device	3	1	4
Control room/computer room	8	13	21
Totals	11	14	25

6. If two or more sets of memory modules were provided for PEAM, they could be placed in one central location or placed at different locations onboard ship. Which type of arrangement do you think would be better and why?

	CV	DD 963	Totals	Why?
Centralized	2	7	9	Located with devices.
Decentralized	8	6	14	Convenience, one set with each device; better survival chances in case of attack.
Totals	10	13	23	

7. Several approaches could be used for organizing and storing SEASPARROW maintenance information on PEAM memory modules. For example, a "functional" approach could be used in which all relevant information for each subsystem of the SEASPARROW (e.g., the director) would be stored on one memory module. Alternatively, a "systems" approach could be used in which FOIDs for the entire SEASPARROW system could be placed on one module, IPB information on another, and so on. Which approach do you think would be better and why?

	CV	DD 963	Totals	Why?
Functional approach	10	7	17	Convenience; don't have to search for each unit; used to having arranged this way.
Systems approach	0	6	6	
Both approaches	1	0	1	Use functional approach for FOIDs but other approach for system-level testing/configuration management information.
Totals	11	13	24	

8. What sort of labeling do you think should be put on the outside of the PEAM memory modules to provide a general overview of their contents?

	CV	DD 963	Totals
Identify by function/subsystem	9	11	20
Identify by system	0	2	2
Identify by reference number--similar to tech. manuals	2	0	2
Totals	11	13	24

9. If the maintenance information for the entire SEASPARROW system requires 10 or more modules, what type of indexing or cross-referencing system do you think would be best for locating <u>specific</u> information contained on each module?

	CV	DD 963	Totals
Table of contents for all memory modules stored on a separate module	5	9	14
Each module applied to specific unit--then broken down by chapter and subsection	4	3	7
Totals	9	12	21

Section 2

Interview Questions Regarding Logistical Support Considerations

The next three questions deal with facilities for updating, correcting, and reproducing technical information stored on PEAM memory modules.

10. One method for updating and correcting the PEAM modules would be to assign this responsibility to shore-based activities only. Another would be to provide the necessary facilities to perform authorized reprogramming of the modules onboard ship. Which method do you think would be better and why?

	CV	DD 963	Totals	Why?
Shipboard	5	7	12	Shipboard techs--know what needs updating; can be accomplished quicker and more efficiently; accountability.
Shore-based command	6	6	12	Shore activity can research first and send to all ships at once; standardization, better quality control; fleet personnel more apt to damage modules.
Totals	11	13	24	

11. Because PEAM memory modules might be damaged or lost in everyday use, some sort of backup capability must be provided. One method for obtaining backup copies of the memory modules would be to order them from shore-based activities. Another would be to provide the necessary facilities to reproduce PEAM memory modules onboard ship. Which method do you think would be better and why?

	CV	DD 963	Totals	Why?
Shipboard	7	9	16	Replacement could be obtained quicker; save time, money, paperwork.
Shore-based	4	4	8	Trust shore-based facility more; more manpower available.
Totals	11	13	24	

12. If the foregoing updating, correcting, and backup capabilities were provided onboard ship, who do you think should have the responsibility for performing these duties?

	CV	DD 963	Totals
SEASPARROW technicians	9	12	21
Technical Library	1	0	1
Totals	10	12	22

The next two questions concern possible environmental conditions found onboard ship that might damage or degrade the PEAM device and memory modules.

13. Do you think that PEAM might be damaged or degraded by emissions from shipboard transmitters? If so, specify the location(s) and operating conditions in which you think such a problem might occur.

	CV	DD 963	Totals	Why?
Yes	6	5	11	If used near radars/transmitter; when used outside on launchers and directors.
No	5	6	11	
Totals	11	11	22	

14. Can you think of any other type(s) of environmental conditions onboard ship that might damage or degrade the PEAM device or memory modules? If so, specify which condition(s) and what adverse effect(s) you can foresee.

	CV	DD 963	Totals	Why?
Yes	5	8	13	Rain and/or salt water; vibration; high temperatures; loss of A/C current or surge; dirt.
No	6	4	10	
Totals	11	12	23	

The next two questions concern the need for providing logistics support for the PEAM device itself after contractor-provided services have been terminated.

15. Responsibility for the maintenance and spare parts supply for PEAM could be assigned on a departmental basis: or alternatively assigned to a specific Navy rating or work center. Which method do you think would be better?

	CV	DD 963	Totals
Own department	8	9	17
Specific Navy rating	2	2	4
Totals	10	11	21

16. What method do you think would be best for presenting the technical information needed to perform preventive and corrective maintenance on the PEAM device itself?

	CV	DD 963	Totals
PMS cards/technical manuals	6	7	13
PEAM module	3	4	7
Totals	9	11	20

The next three questions concern the inclusion of a "print-on-demand" capability for PEAM.

17. Can you think of any situations and/or conditions that would require you to obtain paper copies of the information contained in the PEAM memory modules? If so, please specify what these might be.

	CV	DD 963	Totals	Why?
Yes	5	12	17	Have information to CASREP a system; use for bookmark in troubleshooting process; permit 2 techs. to work at same time; maintain fault histories--record keeping; use for training; taking into remote locations.
No	5	1	6	
Totals	10	13	23	

18. If a print-on-demand capability were provided, where do you think the printer unit should be located?

	CV	DD 963	Totals
Where PEAM is stored	5	0	5
Mounted somewhere in control space/computer room	4	9	13
Don't need capability	2	0	2
Totals	11	9	20

19. Although there may be advantages to having a print-on-demand capability, can you foresee my problems with its use? If so, please specify.

	CV	DD 963	Totals
Have to do PMS & repair/maintain another piece of equipment	7	3	10
Infrequent use, costly	2	0	2
No paper/ink supplies in stock	1	2	3
No problems	2	9	11
Totals	12	14	26

Section 3

Interview Questions Regarding Training Considerations

The questions in this section deal with methods for teaching NSSMS technicians how to operate PEAM and its potential for supporting other types of shipboard training.

20. What do you think would be the best method for presenting the information needed to learn the basic operation of PEAM on board ship?

	CV	DD 963	Totals
Demonstration/instruction book	5	5	10
PEAM module	1	0	1
Have work center supervisor teach others by OJT	1	4	5
Using PMS cards	1	0	1
School course	0	4	4
Totals	8	13	21

21. Do you think that preliminary training on the operation of PEAM should be provided in Class "A" or "C" schools? If so, specify which school you think would be the most appropriate.

	CV	DD 963	Totals
"A" School	1	0	1
"C" School	6	11	17
Both	3	0	3
Not in school	1	1	2
Totals	11	12	23

22. Are there any other shipboard training applications that you think PEAM could support? If so, please specify what type of training this might include.

	CV	DD 963	Totals
General damage control/general maintenance training	1	2	3
EPICS training	1	2	3
All fire control equipment	1	2	3
Any electronic troubleshooting	1	0	1
Deck preservation	0	1	1
None	5	1	6
Totals	9	8	17

Section 4

Interview Questio. s Regarding Interface Considerations

The last two questions deal with the need for interfacing PEAM with other devices to expand its present capabilities and functions.

23. Are there any functions, capabilities, or procedures for diagnosing faults in the SEASPARROW system that you would like to see interfaced with the PEAM device? If so, please specify.

	CV	DD 963	Totals
Capability for feeding symptoms into PEAM and have it diagnose fault, and tell technician where to begin	5	3	8
Computer or SEAT	3	5	8
Verbally giving requirements for proper operation	1	0	1
No	1	4	5
Totals	10	12	22

24. Are there any logistical support functions for the SEASPARROW system that are currently performed manually that you would like to see "automated" by means of a PEAM interface unit? If so, please specify what these functions might include.

	CV	DD 963	Totals
Capability of punching in Ref Des and have PEAM tell me part No. and NSN for desired component	1	0	1
List of APLs, NSNs	1	3	4
Report writing	0	3	3
Voltage readings	0	1	1
System checks thru SEAT	0	1	1
None	9	4	13
Totals	11	12	23

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